A
COMPENDIOUS SYSTEM
OF
Natural Philoſophy,

With NOTES.

Containing the

Mathematical Demonſtrations,

AND

Some Occaſional REMARKS.

PART II.

HYDROSTATICKS and PNEUMATICKS.

To which are annexed ſome DISSERTATIONS
relating to theſe Subjects.

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A
COMPENDIOUS SYSTEM
OF
Natural Philoſophy.

PART II.
HYDROSTATICS.

CHAP. I.

Of the Phænomena which ariſe from the mutual Action of the Particles of Fluids upon one another.

I. IN the former Part of this Eſſay, I have laid down and explained the general *Laws of Nature*, and from thence deduced thoſe Phænomena, which are in a ſtrict and proper Senſe [*] denominated *Mechanical*: I pro-

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[*] In a larger Senſe, all the Effects and Operations of natural Bodies upon one another may be called Mechanical; as being all ſubject to the general Laws of Motion. In Hydroſtatics Fluids are governed by the Laws of Mechaniſm, as much as the Mechanical Powers themſelves are; the ſame holds of the

I proceed now to an Explanation of ſuch, as Philoſophers have comprehended under the Name of *Hydroſtatics*; the Intention of which is to explain the Nature of *Fluids*, and the Manner wherein they act upon one another, and upon Solids.

II. The Nature of a *Fluid**, as diſtinguiſhed from that of a *Solid*, or hard Body, conſiſts in this, *viz.* that its Particles are ſo looſely connected together, that they readily move out of their Places, when preſſed with the leaſt Force one Way more than another †. From whence Philoſophers conclude, that they

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Rays of Light, as will be ſeen when we come to Optics; and in the larger Bodies of the Planetary Syſtem, Mechaniſm equally prevails, as has been demonſtrated by Sir *Iſaac Newton*; which we ſhall endeavour to make out when we treat of the Phyſical Cauſe of the Motion of the Heavenly Bodies.

* Some Philoſophers make the following Diſtinction in Fluids; thoſe which flow or ſpread themſelves till their Surfaces become level or horizontal, they call *Liquid*; in Contradiſtinction to Flame, Smoak, Vapour, &c. which are alſo Fluids, but do not acquire ſuch a Surface. Thoſe, which are capable of exciting in us the Idea of Moiſtneſs, as Water, &c. they call *Humid*, diſtinguiſhing them thereby from Air, Quickſilver, and melted Metals. But thoſe Diſtinctions are quite unneceſſary in a Philoſophical Senſe; the Surfaces of all Fluids being level, when not prevented by the Bodies about them; and Humidity is only a *relative* Quality; for tho' Quickſilver will not moiſten, or ſtick to a Man's Hand, it will to Silver or Gold.

† The common Definition, *Fluidum eſt cujus partes impreſſioni cuicunque cedunt, & cedendo facillimè moventur inter ſe*, though it expreſſes very well the Nature of a *compreſſible* Fluid, as Air, yet does not correſpond to that of Water, whoſe Parts have been found to yield to no Force, with which they have been compreſſed,

they are exceedingly minute, ſmooth, and round *; it being otherwiſe impoſſible they ſhould

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compreſſed, unleſs it was greater on one Side than on the other. The Definition therefore ſeems imperfect, as not expreſſing that *Inequality* of Preſſure, which is requiſite to move the Parts of ſome Fluids one among another.

* It is commonly obſerved that the Roundneſs of the Particles conduces very much to Fluidity, not only as it diſpoſes them to move one among another with greater Facility, but becauſe round Bodies touching one another in few Points only, the Force with which they mutually attract each other, is the weaker. But, upon this Suppoſition, the Particles of a Fluid ought to move with leſs Freedom one among another, by how much the greater the Weight is, with which they are compreſſed (for it is the ſame thing in this reſpect, whether they preſs againſt each other by Virtue of their own Attraction, or by ſome external Force) but of this we have no Experience. A Diver, upon plunging out of his Bell at the Bottom of the Sea, never finds the Water leſs fluid, notwithſtanding the great Preſſure from above. Mr. *Boyle* having cauſed a Tadpole to be put into a Veſſel of Water, and to be preſſed with a very great Force, tells us, that in Appearance it found no Inconvenience from thence, but ſwam about with the ſame Freedom and Briſkneſs as ever.

Quere, Whether the Particles of which Fluids conſiſt, are in Contact with each other, or not? Perhaps, they are prevented from approaching, nearer than to a certain Diſtance, by a repelling Power, diffuſed around each ſingle Particle. The Obſervation, that Water is not render'd leſs fluid by Preſſure, ſeems to favour this Opinion; and the Property, which the Air has of expanding or contracting itſelf, according to the Weight which it ſuſtains (as ſhall be ſhewn, Chap. 3.) proves beyond Contradiction, that its Particles are endued with ſuch a Power. But then if the Particles of all Fluids have this Power, it will follow that they ought to be in ſome Meaſure capable of being reduced into leſs Space by Preſſure, as Air is; which they have not as yet been ſhewn to be. Further, ſince it has been proved (Part I. Chap. 3.) that if the Parts of Fluids are placed juſt beyond their natural Diſtances from each other, they will approach and run together, and if placed farther aſunder ſtill, will repel each other; it follows, upon the foregoing Suppoſition, that each ſhould move with ſuch Freedom one among another, upon the leaſt Inequality of Preſſure.

III. Thoſe Particles, conſidered ſeparately, are endued with all the common Properties of Matter, and ſubject to the ſame Laws of Motion

Particle of a Fluid muſt be ſurrounded with three Spheres of Attraction and Repulſion one within another: the innermoſt of which is a Sphere of Repulſion, which keeps them from approaching into Contact; the next, a Sphere of Attraction diffuſed around this of Repulſion, and beginning where this ends, by which the Particles are diſpoſed to run together into Drops; the outermoſt of all, a Shere of Repulſion, whereby they repel each other, when removed out of that Attraction.

Now, if this *Hypotheſis* ſhould be found to be true; and we might, agreeably to the above-mentioned Conſequence of it, ſuppoſe, that the Particles of all Bodies attract and repel each other *alternately* at different Diſtances, perhaps we might be able to ſolve a great many Phænomena relating to ſmall Bodies, which now lie beyond the reach of our Philoſophy. However, upon the Suppoſition of the three Spheres of Attraction and Repulſion juſt mentioned, nothing is more eaſy, than to ſee how Solids may be converted into Fluids, and Fluids into Solids (as is done in Liquefaction and Freezing;) for allowing, that the firſt or innermoſt Sphere of Repulſion is capable, like that of the Particles of Air, of being augmented by Heat, and diminiſhed or totally ſuſpended by Cold, it follows that Bodies muſt be more or leſs fluid, in Proportion to the Degree in which they are affected by Heat or Cold: for when the Action of the firſt Sphere of Repulſion is diminiſhed or deſtroyed by Cold, the Particles of the Fluid muſt neceſſarily be brought into cloſer Contact with each other by the Force of the circumambient Attraction, and by that means conſtitute an harder Body than before. But, we muſt not dwell too much upon an Hypotheſis which wants Proof; I ſhall only add, that altho' ſome Fluids, as Water, have not been *as yet* contracted in their Dimenſions, or made to take up leſs Space than they naturally do, by any Force with which they have been compreſſed by *Art*; yet there are none but are *naturally* contracted by Cold, from whence it ſeems reaſonable to infer, that their Particles are at leaſt *capable* of being brought into cloſer Contact, which is ſome Confirmation of this Doctrine.

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Motion and Gravitation with larger Bodies. To enquire therefore into the Nature of Fluids, is to conſider, what Appearances a Collection of very ſmall round Bodies, ſubject to thoſe Laws, will exhibit under different Circumſtances. In order to which, it is uſual with Hydroſtatical Writers to conſider a Fluid, as divided into ſeveral perpendicular Columns contiguous to each other. Sometimes it is convenient to conceive it divided into thin Plates or *Strata* lying upon one another. In ſome Caſes, the ſame Fluid is conſidered, as diſtinguiſhed both theſe Ways, *viz.* into perpendicular Columns, and alſo into thin Strata or Plates. Figure 1. repreſents a Veſſel filled with a Fluid to the Height EF, and divided into the Columns GH, IK, LM, *&c.* and alſo into the Strata RS, TV, XY, *&c.*

IV. From this Obſervation, concerning the Properties of the Particles conſidered ſeparately, immediately reſults the following Propoſition, *viz.* that in a Veſſel, whoſe Form is ſuch as repreſented by ABCD, (*Fig.* 1.) the Quantity of Preſſure, which each Stratum ſuſtains from the Weight of the incumbent Fluid, is in Proportion to the Number of thoſe Strata,

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It is an obvious Objection to this, that Water by freezing is augmented in its Bulk; but this may be owing to thoſe Bubbles or Vacuities, obſervable in the Water after it is frozen, which were not in it before; and not to any general and uniform Removal of the Particles of the Fluid from each other, which the Objection, if it is of any Force againſt what has been advanced, muſt ſuppoſe.

Strata, which reſt upon it, that is, as the Height of the Surface of the Fluid above it; for if we ſuppoſe the Strata of equal Thickneſs, the Quantity ſuſtained is proportionable to the Number of Strata of which it conſiſts.

V. When the Surface of a Fluid is horizontal or level, each Particle thereof is diſpoſed to continue in its Place, being ſuſtained therein by the contiguous ones.

Let the Fluid be ſuppoſed to be divided into Strata, each of the Thickneſs of a Particle of the Fluid; and if the Truth of this Propoſition be denied, let the Particle *mn* be one of thoſe which is not ſuſtained in its Place by the contiguous ones, but is moving from thence towards ſome other Part of the Veſſel, *v. g.* towards D. Now, ſince all the other Particles of that Stratum are at an equal Depth below the Surface of the Fluid with this, they alſo ſuſtain an equal Degree of Preſſure (by the laſt Propoſition,) conſequently for the ſame Reaſon that one of them is moving towards D, the reſt may all be ſaid to be moving in the ſame Direction: but this cannot be true of the whole Stratum, while the Veſſel is entire, and therefore of none of its Parts. Now, the like Reaſoning will hold againſt the Motion of the Particle *mn* towards any other Part of the Veſſel; from whence it follows, that each Particle of the Fluid is ſuſtained in its Place by the contiguous ones, and therefore diſpoſed to continue at Reſt.*

VI. From hence is derived a fundamental Propoſition in Hydroſtatics, *viz.* That when the Surface of a Fluid is level, whatever Preſſure any ſingle Particles or ſmall Portion of it ſuſtains from the contiguous ones on one Part, it ſuſtains the ſame on all the reſt; that is, it is preſſed by them with an equal Degree of Force on all Sides †.

For, by the Definition of the Fluid (§. 2.) each Particle is diſpoſed to give Way, and move out of its Place, when the Preſſure is not equal on all Sides; and (§. 5.) each Particle is preſſed by the contiguous ones in ſuch a Manner, that it is ſuſtained in its Place thereby; it is therefore preſſed with an equal Degree of Force on all Sides.

Corol. From hence it follows, that each Particle or ſmall Portion of a Fluid preſſes with the ſame Degree of Force in all Directions on thoſe which are contiguous to it. For, by the third Law of Nature, every Par-

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* This ſhews us the Abſurdity of ſome Philoſophers, who make the Nature of a Fluid, as contradiſtinguiſhed from that of a Solid, to conſiſt ſolely in the inteſtine Motion of its Particles.

† This Propoſition, with its Corollary, is not ſtrictly ſpeaking true, unleſs the Particle or Portion of Fluid we ſpeak of is ſuppoſed void of Gravity, for it preſſes downwards with a Force equal to the Weight of thoſe Particles which reſt upon it, added to its own; whereas the Force with which it preſſes upwards is only equal to the Weight it ſuſtains, *viz.* that of the incumbent Fluid. But the Particles of Fluids are ſo exceedingly minute, and the Gravity of each ſo very ſmall, that the Error ariſing from hence is inſenſible.

ticle preſſes upon the contiguous ones with the ſame Degree of Force, with which it is preſſed upon by them.

VII. The Surface of a Fluid becomes level by its own Gravity, when no external Force prevents it being ſo.

For, the Particles of Fluids preſs in all Directions with Forces proportionable to the Height of their Surfaces (Cor. §. 6. and §. 4.) If then the Surface be not level, the different Parts of the ſame inferior Stratum will be preſſed not only downwards, but ſideways againſt each other with unequal Forces; the greater Preſſure therefore overcoming the weaker, the Particles which ſuſtain the leaſt Preſſure, will be driven out of their Places and raiſed up, till the Surface becomes level; the Surface being level, each Particle will be equally preſſed in every Direction, (§. 8.) all therefore will remain at Reſt, and the Surface continue in that State *.

VIII.

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* This Demonſtration, and alſo both the foregoing, are founded upon a Suppoſition, that Bodies tend downwards by their Gravity in Lines parallel to each other, which though *phyſically* true, is not ſtrictly ſo, their Tendency being towards the Center of the Earth, and conſequently in Lines which meet in a Point: and therefore, if we would be accurate, the Fluid contained in a Veſſel ſhould be conſidered, as divided into Columns and Strata, as repreſented Figure the ſecond, where ABD is the Earth, C its Center, EFGH a Fluid contained in a Veſſel, and divided into Columns, which if continued down to the Center of the Earth, would there terminate in a Point C; and into the concentric Strata, *ab*, *cd*, &c. having the Center of the Earth for the Center of their Convexity. And then we ſhould

VIII. Fluids gravitate in Fluids of the ſame Kind.

This Propoſition is a neceſſary Conſequence of what has been obſerved about the Nature of the Particles of which Fluids conſiſt, *viz.* that they are ſolid, and endued with the ſame Properties with other Bodies. The Reaſon why their Gravity is not ſenſible in the Fluid, is becauſe the lower Parts ſuſtain the upper, and hinder them from deſcending. But, it does not follow from thence, that the Gravity of the uppermoſt is entirely taken away, as ſome * Philoſophers have imagined; for, as

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ſhould find that the Particles of the Fluid will not be in Æquilibrio with each other, till all the Parts of its Surface are at equal Diſtances from the Center of the Earth, forming thereby the Surface EF, concentric to that of the Earth. For, ſuppoſing the Fluid EFGH continued down to C, ſo as to fill the Space ECF; it is evident the Columns, into which the Fluid is divided, cannot be of equal Lengths, and therefore cannot be of an exact Counterpoiſe to each other, unleſs the Surface EF is a Portion of a Sphere, whoſe Center is C: but the Action of the Parts of the Fluid upon each other at the Surface, is the ſame, whether the lower Part GCH be a Fluid, or not. Conſequently the Surfaces of Fluids are not level or plain, but convex, having the Center of the Earth for the Center of their Convexity.

This Convexity, by Reaſon of the great Diſtance of the Earth's Center, approaches ſo near to a Plane, that in ſmall Portions of it, the Difference is not ſenſible, and therefore may be neglected: but at Sea, 'tis evident to Senſe; for when the Mariners put to Sea, the Shore firſt diſappears, then the lower Buildings, afterwards the Towers, Mountains, *&c.* in like Manner, when they approach a diſtant Ship, the Top of its Maſt and Sails appear firſt, while the Ship itſelf is intercepted from their View, by the Convexity of the Water between them.

* This was the Notion of the *Carteſians*, who held, that when a Fluid is mixed with another of the ſame Kind it loſes its own Weight thereby.

much as the lower Parts preſs againſt the upper in ſuſtaining them; juſt ſo much do the upper by their Re-action preſs upon the lower. Thus, the Weight of the whole Fluid is communicated to the Veſſel, which therefore weighs according to the Quantity it contains, notwithſtanding the Preſſure of each Portion of the Fluid, taken ſeparately, ſeems not to affect it.

IX. The Preſſure of a Fluid is in Proportion to its perpendicular Height, and the Quantity of Surface againſt which it preſſes.

This Propoſition admits of four Caſes.

1. When the Fluid is contained in a Veſſel of the ſame Dimenſions, from Top to Bottom, and held in an erect Poſition, as that repreſented Fig. 1. it is evident, the Preſſure of the Fluid upon the Bottom will be in Proportion to its Magnitude, and the perpendicular Height of the Surface of the Fluid above it. For, conceiving it divided into Columns, the Preſſure upon the Bottom, by the fourth Propoſition, will be as the Length or Height of the Columns: and it will alſo be as the Number of them, becauſe the Quantity of Fluid, which preſſes upon the Bottom, is in that Proportion, that is, as the Magnitude of the Bottom preſſed upon. But when the Veſſel is inclined or irregular, the Truth of this Propoſition is ſo far from being evident, that it has been commonly looked upon as a Paradox.

2. Let the Veſſel ABCD (*Fig.* 3.) be filled with a Fluid to the Height EF, and held in an inclined Poſition, as there repreſented; I ſay, the Preſſure of the Fluid is proportionable to the Magnitude of the Baſe CD, and FG or HD the perpendicular Height of the Surface of the Fluid above it.

For ſuppoſing the Fluid divided into the Strata EI, KM, LO, *&c.* ſo far, as the firſt Stratum EI is prevented from preſſing upon KI the Surface of the next inferior Stratum, by being in ſome Meaſure ſupported by the Side of the Veſſel FI, ſo far is its Preſſure augmented by the Re-action of the oppoſite Side EK upon it, which is exactly equal to the Action of the former, becauſe the Fluid preſſing every Way alike, at the ſame Depths below the Surface, exerts an equal Force againſt both theſe Sides. The Surface therefore of the ſecond Stratum is preſſed with the ſame Degree of Force with which it would be, if the Quantity of Fluid contained in the former Stratum was included within the Space HKQI, which is exactly equal to it, as having the ſame Baſe KI, and the ſame perpendicular Height QI *. Now, this being true of each Stratum, their Preſſure upon CD the Baſe of the Veſſel is the ſame, as if they were all placed perpendicularly over it, and filled the Space RHCD; which they would do, ſince the Sum of their perpendicular Height QI, KS, LT and NV are equal to HD the perpendicular Height of this Space, and each of their Baſes KI, LM, *&c.* is equal to CD its Baſe †. But, by the foregoing Caſe, if the Space RHCD was filled with a Fluid, the Preſſure of it would be proportionable to the Dimenſions of the Baſe CD, and the perpendicular Height DH, therefore it is the ſame in the inclined Tube ABCD ‖.

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* 31. *El.* 11.

3. Let the Veſſel ABC be irregular, as repreſented *Figure* the fourth, and filled with Fluid to the Height D, I ſay, the Preſſure of the Fluid upon the Baſe C, is proportionable to the Magnitude of the Baſe, and CD the perpendicular Height of the Surface of the Fluid above.

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† 31. *El.* 11.

‖ Perhaps it may be thought more Geometrical, to demonſtrate this Propoſition with the Generality of Authors from the Property of the inclined Plane. They conſider AD the lower Side of the Tube, as an inclined Plane, on which the Fluid contained within it reſts, and argue that it loſes thereby a Part of its Weight in Proportion to the Length of the Plane, and therefore occaſions no greater Preſſure upon the Baſe, than if the Veſſel was held erect, and filled only to the ſame perpendicular Height, as when inclined. But this Demonſtration proves too much, for by this Way of Reaſoning, one might ſhew, that the Preſſure of the Fluid EFCD upon the Baſe CD is leſs than the Preſſure of RHCD a Column of the ſame Fluid having the ſame Baſe and equal perpendicular Height with it. For both the inclined, and the perpendicular Column contain the ſame Quantity of Fluid, upon Account of the Equality of their Baſes, and perpendicular Heights; but that reſts upon an inclined Plane, which this does not, and therefore preſſes leſs upon the Baſe. But this is contrary both to Demonſtration and Experience, the Argument therefore proves too much.

In order that the Proof of this Propoſition may be the better underſtood, we muſt premiſe the following *Lemma*, viz.

That when a Fluid paſſes through a Pipe, as AB, (*Fig.* 5.) which in ſome Parts is larger than in others, the Moment, or Force with which it moves, is every where the ſame. For while the Fluid is paſſing through the Tube, its Velocity in every Part will be reciprocally as the Quantity of Matter; for Inſtance, it will be as much greater at C, than it is at D, as the Quantity paſſing through C at any Inſtant of Time, is leſs than at D, and ſo of the reſt; becauſe a leſs Quantity would be conveyed through the ſmaller Parts of the Tube in the ſame Time, unleſs it ſhould move faſter there in Proportion to the Smallneſs of them. Now the Momentum of Bodies is partly owing to the Quantity of Matter, and partly to the Velocity; (as explained Part I. Chap. 9. §. 1.) conſequently what the Fluid, which is actually paſſing through the narrower Parts of the Tube, wants in Quantity, is compenſated by its Velocity in thoſe Parts, and what it wants in Point of Velocity in the other Parts, is made up by the Quantity paſſing through them; ſo that the Moment is the ſame in every Part of the Tube, whether larger or narrower *. The ſame is true, whatever be the Poſition the Tube is held in.

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* Thus, we may obſerve in a River or Canal, that by how much the Breadth or Depth is leſs in any Part, ſo much the

Let us now conceive the Fluid in the Veſſel ABC (*Fig.* 4.) to be diſtinguiſhed into the Strata EF, GH, IK, *&c.* Let us alſo imagine the Bottom of the Veſſel C to be moveable, that is, capable of ſliding up and down the narrow Part of the Veſſel, *v. g.* from C to GH, (without letting any of the Fluid run out.) Let it further be ſuppoſed that this moveable Bottom, is drawn up or let down with a given Velocity, while the Veſſel itſelf is fixed and immoveable; it is evident the lowermoſt Stratum, which is contiguous to the Bottom, will be raiſed or let down with the ſame Velocity, and will thereby have a Moment proportionable to that Velocity, and the Quantity of Matter it contains: But by the Lemma, all the reſt of the Strata will have the ſame Moment, conſequently the Moment of all taken together, (that is, of the whole Fluid,) is the ſame, as if the Veſſel had been no larger in any one Part, than it is at the Bottom, (for then the Moment of each Stratum would alſo have been as great as that of the lowermoſt;) the Preſſure therefore, or Action of the Fluid, with which it endeavours to force the Bottom out of its Place, is as the Number of Strata, that is, the perpendicular Height of the

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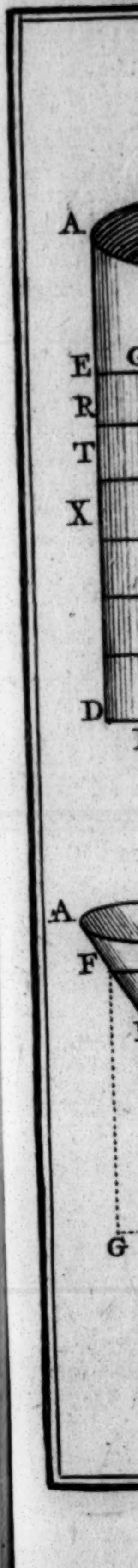
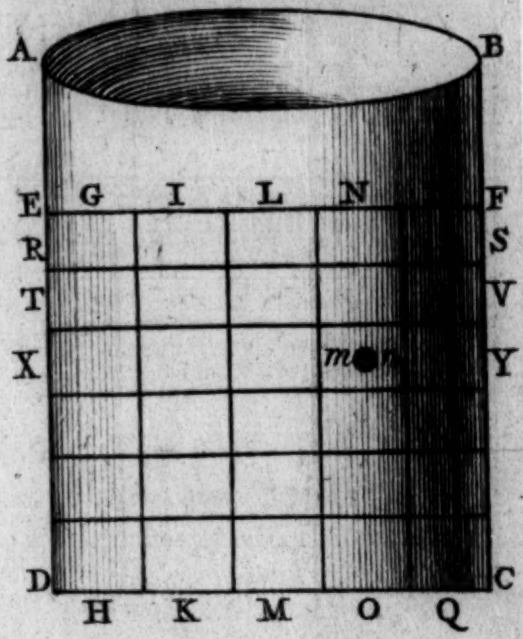
more rapid is the Stream in that Part; and on the contrary, where it is wider and deeper, the Motion of the Water is more gentle and languid. So that the Moment, with which it flows, is the ſame in every Part.

Fluid,

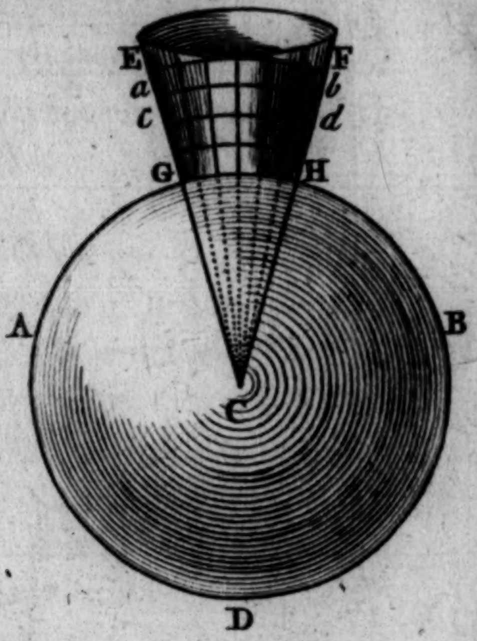


Part II. Plate I. p. 16.

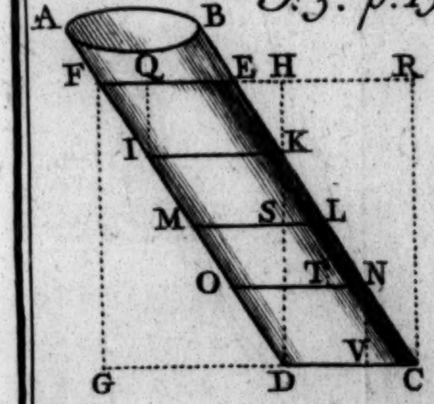
F. 1. p. 7.



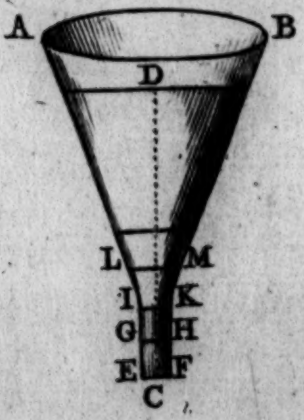
F. 2. p. 11.



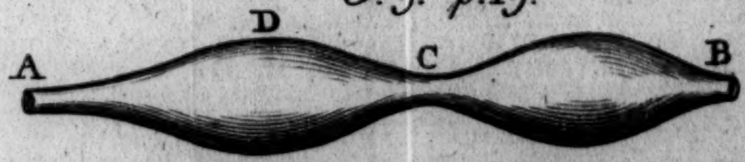
F. 3. p. 13.



F. 4. p. 14.



F. 5. p. 15.



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Fluid, and the Magnitude of the lowermoſt Stratum, that is, the Bottom.

Again, ſuppoſe the Veſſel ABC (*Fig.* 6.) fill'd with a Fluid to D; I ſay the Preſſure upon the Bottom BC, is proportionable to the Dimenſions of the Bottom, and to DE the perpendicular Height of the Fluid.

For, if we ſuppoſe the Bottom moveable, as before, and raiſed up or let down with a given Velocity, the Moment of every Stratum will be the ſame with that of the lowermoſt, by the Lemma; therefore the Moment of all taken together, is the ſame, as if the Veſſel had been no leſs in any one Part, than it is at the Bottom; conſequently the Preſſure is proportionable to the perpendicular Height, and the Magnitude of the Bottom. This Caſe is the Converſe of the former*.

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* Upon this is founded the Practice of conveying Water through Pipes from Place to Place, &c. For from hence it follows, that if one End of a Pipe is laid in a Reſervoir of Water, the Fluid will run into the Pipe, till it riſes to a Level at the other End with its Surface in the Reſervoir. Thus let ABC (*Fig.* 8.) repreſent a Reſervoir or Baſon of Water, DGE a Pipe laid from thence to E If E the End of the Pipe is placed above the Line ABF, the Level of the Water in the Reſervoir, the Water will run into the Pipe, till it riſes in the other End to F the Level with AB; at which Time the Water in the Pipe will be in Æquilibrio with that in the Reſervoir, and remain at Reſt. But if the End of the Pipe is below the Surface of the Water in the Reſervoir, it will continue to run out, till they are reduced to a Level. For, let GH be the loweſt Part of the Pipe, then ſince F the perpendicular Height of the Fluid on one Side, is equal to B the perpendicular Height of the Fluid on the other, and GH, which (being the Place where

From hence it follows, that, if a Veſſel is made of ſuch a Form, as is repreſented (*Fig.* 7.) by ABCDEFG, and filled with a Fluid to the Height C, the Weight which the Bottom ſuſtains, is as great as it would be, had the Veſſel been IKFG (which is every where of the ſame [Dimenſions, that the other is of at the Bottom) and filled to the Top IK. Becauſe the Preſſure, by the Propoſition, is proportionable to the Bottom and perpendicular Height, which in both Caſes are the ſame *.

X. The

where the Fluids preſs one againſt another) may be conſider'd as a Baſe to both, is common; it follows from this Propoſition, that the Preſſures on each Side are exactly equal; and therefore being in contrary Directions will neceſſarily deſtroy each other, and the Fluid will remain in Æquilibrio. But while the End E is below the Level, this Æquilibrium cannot be obtained; and therefore the Fluid will continue to run out.

For the ſame Reaſon, when two or more Tubes communicate with each other, the Surface of the Fluid they contain will ſtand at the ſame Level in all.

* The Reaſon why the Veſſel ABCDEFG, within the Fluid contained in it, does not weigh ſo much, as the Veſſel IKFG, when full to the ſame Height, notwithſtanding the Preſſure upon the Bottom is the ſame in both, is, becauſe ABDE the upper Part, or Cover of the former Veſſel, is preſſed upwards by the Fluid below it, with a Force equal to the Endeavour the Fluid in the ſmall Tube BCD has to deſcend. Which Endeavour is the ſame that it would be, if the Tube BCD comprehended alſo the two Spaces ICBA and CKED, its Moment being the ſame in both Caſes by the Demonſtration; the Cover therefore is preſſed upwards with a Force equal to the Weight of as much Fluid as would fill the two Spaces ICBA and CKED; conſequently the Veſſel, whoſe Form is ABCDEFG, is ſo much lighter than the other, that is, as much as the Fluid it contains is leſs.

From

X. The Velocity, with which a Fluid ſpouts out at an Hole in the Bottom of a Veſſel, is equal to that, which a Body would acquire by falling freely from the Level of the Surface of the Fluid to the Hole.

Let there be a large cylindrical Tube ABCD (*Fig.* 9.) in the upper Part of which let us imagine a Cylinder of Ice FGHI exactly fitting it; let it further be ſuppoſed, that HI, the lower Surface of the Ice, is continually melting, ſo as to afford a Stream of Water running down the Middle of the Tube. Now the Form of this Stream of Water will neceſſarily be ſuch, as is repreſented in the Figure by HLI; for the Water falling freely will deſcend faſter and faſter like other Bodies, cauſing thereby the Stream to become narrower and narrower. Now, let it be ſuppoſed, that the Tube has a Bottom, as CD, with an Hole in it at K, juſt ſufficient to let the Stream paſs freely; it is evident, there will be no Obſtruction on this Account, but that the

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From hence ariſes this Paradox, that the leaſt Quantity of Fluid may be made to raiſe any Weight how great ſoever it be.

For ſince the Cover ABDE is preſſed upwards with a Force equal to the Weight of as much Fluid, as would fill the two Spaces ICBA and CKED, and thoſe Spaces may be enlarged at Pleaſure in Height, by lengthening the Tube BCD (which at the ſame Time muſt be made proportionably ſmaller, otherwiſe the ſame Quantity of Fluid will not fill it;) it follows, that the ſame Quantity of Fluid may be made to preſs the Cover upwards with a given Force; if that Cover then is made moveable, any Weight that is laid upon it may be ſupported thereby.

Fluid will paſs through the Hole with ſuch Velocity, as it naturally acquires by falling from HI, the lower Surface of the Ice. And if we ſuppoſe M and N, the empty Parts of the Tube, to be filled with Water, the Water will preſs equally upon the Sides of the Stream in every Direction (§. 6.) and therefore will be no Impediment to its Motion on that Account. Laſtly, let us ſuppoſe the Ice taken away, and the Stream ſupplied from the Water at the Sides, as is the Caſe when a Fluid runs out through the Bottom of a Veſſel; then will the Velocity, with which the Water flows through the Hole, continue the ſame; for ſo far as the Water coming from the Sides, endeavours to deſcend itſelf, ſo far it obſtructs the Deſcent of the Stream, and no farther; and conſequently cauſes no Alteration in the Velocity or Quantity of Fluid running out. The Velocity therefore, with which the Fluid paſſes through the Hole, is equal to that, which a Body would acquire by falling freely from the Level of the Surface of the Fluid to that Place.

If the Hole is made in the Side of the Veſſel at the ſame Diſtance below the Surface, the Velocity will be the ſame, on Account of that equal Tendency Fluids have to move every Way alike *.

XI. The

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* Upon this Principle is founded the Practice of making artificial Fountains. For if to a Veſſel or Reſervoir ABCD, (*Fig.* 10.) filled with a Fluid to the Height EF, be fixed the Pipe

XI. The Velocity, with which a Fluid ſpouts out from the Bottom or Side of a Veſſel, is as the ſquare Root of the Height of its Surface above the Hole *.

The Cauſe, why a Fluid ſpouts out through an Hole made in the Bottom or Side of a Veſſel, is the Preſſure or Weight of the Fluid incumbent upon the Hole; from whence it ſhould ſeem, that the Velocity ought to be as the Preſſure; but if ſo, then the Quantity

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Pipe CH, with a ſmall Aperture at K, the Fluid will ſpout up from thence to FL, the Level of the Surface of the Fluid in the Veſſel. For, by this Propoſition, it will ſpout from K with ſuch a Velocity, as a Body would acquire by falling from FL, the Level of the Surface, to the Aperture at K; that is, ſuch as will carry it from the Aperture to the Level; becauſe that Velocity which a Body acquires by falling from a certain Height, is ſufficient to carry it back to the ſame Height from whence it fell.

But in Practice the Height the Fluid riſes to, is leſs than that of the Level of its Surface in the Reſervoir: this is owing to the Reſiſtance it meets with from the Air, its Friction againſt the Sides of the Pipe, *&c.* It is found impoſſible to make it much exceed the Height of an hundred Feet: For, when it ſpouts out of the Aperture with a Velocity neceſſary to carry it higher, the Stream is immediately daſhed to Pieces by the Reſiſtance of the Air; whereby it loſes its Force, and is prevented from riſing to any conſiderable Height.

* This Propoſition may be otherwiſe demonſtrated from the laſt, in the following Manner. For, ſince the Velocity with which a Fluid ſpouts out through an Hole in the Bottom or Side of a Veſſel, is equal to that which a Body would acquire by falling from the Level of the Surface of the Fluid to the Hole, and the Velocities Bodies acquire by falling are as the ſquare Roots of the Heights they fall from (Part I. Chap 5. §. 5.) it follows, that the Velocity, with which a Fluid ſpouts out from an Hole in the Bottom or Side of a Veſſel, is as the ſquare Root of the Height of the Level of the Surface of the Fluid above the Hole.

run out would alſo be as the Preſſure (for, the faſter the Liquor flows, the greater is the Quantity thrown out in a given Time, and *vice verſâ*) conſequently, upon this Suppoſition we ſhould have two Effects, each depending on the ſame Cauſe and equal to it, which is abſurd. 'Tis not then the Quantity of Fluid run out, nor the Velocity with which it flows, but its Moment, or both theſe multiplied together, (Part I. Ch. 9. §. 1.) that is the true and adequate Effect of the Preſſure. Now theſe being ever in the ſame Ratio with each other, 'tis neceſſary, in Order that the Effect may be proportionable to its Cauſe, that each of them be only as the ſquare Root of the Preſſure: For then, being multiplied together, their Product, or the Moment of the ſpouting Fluid, is adequately as the Preſſure which occaſions it; but the Preſſure is as the perpendicular Height (§. 4.) therefore the Velocity, and alſo the Quantity of Fluid ſpouting out, is only as the ſquare Root of the Height of its Surface above the Hole.

To give an Inſtance or two; ſuppoſe two Holes made in the Side of a Veſſel, the one an Inch below the Surface of the Fluid it contains, the other four Inches; the Velocity with which the Liquor flows out of the lower Hole, will not be four Times as great, as that with which it flows through the upper, notwithſtanding the Preſſure is four Times greater: For if it ſhould, the Quantity run out in a given Time would alſo be four Times greater, conſequently the Effect produced would be ſixteen Times greater than it is at the upper Hole, that is, four Times greater than the Cauſe; which is abſurd. Whereas the Velocity and Quantity of Matter will each be only twice as great as they are above, producing thereby a Force or Moment only four Times as great, which is proportionable to the Cauſe. So, if an Hole were made ſixteen Times lower than the firſt, the Velocity and Quantity of Matter will not be each ſixteen Times greater than at the other, but only four Times greater a-piece, and ſo the Moment ſixteen Times greater, as the Preſſure is *.

XII. When

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* From hence, we may ſee the Error ſome of the foreign Mathematicians have fallen into with Regard to the Forces of moving Bodies, who contend that they are as the Squares of the Velocities multiplied by the Quantities of Matter. For, from this Propoſition it is, that one of the principal Arguments brought in Favour of this Opinion is derived. They argue thus, *Effects* are ever proportionable to their *Cauſes*, the *Preſſure* of the incumbent Fluid is the *Cauſe* of its ſpouting out, the *Force* with which it ſpouts out, is the *Effect*; but by this Propoſition the *Preſſure* is as the *Square* of the *Velocity* it flows with, therefore the *Force* is likewiſe as the *Square* of the *Velocity*. True, it is ſo; but let us ſee the Conſequence. The Force, with which the Fluid ſpouts out, is not only owing to the Velocity, but alſo to the Quantity run out in a given Time. They have each their Share in producing the Force, conſequently the Force is in a Ratio compounded of both, or as the Product of one multiplied by the other, or, which comes to the ſame Thing, (ſince as was obſerved before, they are in the ſame Ratio with each other) as the Square of either of them. From hence it is that the Forces of Fluids in Motion are ſaid to be as the Squares of their Velocities; not that they are ſo in Virtue of thoſe Velocites

XII. When a Current of Water, or other Fluid falls, perpendicularly upon the Surface of a Plane, or flows againſt it, (as the Wind againſt the Sail of a Ship, or the like) the Force, which the Fluid exerts upon it, is equal to the Weight of a Column of the ſame Fluid, whoſe Baſe is equal to the Plane, and its Height ſuch, that a Body falling freely through it would acquire a Degree of Velocity equal to that with which the Fluid moves *.

In Order to demonſtrate this Propoſition, let us ſuppoſe the Veſſel ABCD (*Fig.* 11.) filled with a Fluid, and having a large Hole EF in the Bottom, then will the Preſſure of the Fluid cauſe a Stream to flow out, which in the Hole itſelf will have ſuch a Degree of Velocity, as a Body would acquire by falling freely from the Surface of the Fluid in the Veſſel to the Hole (as demonſtrated §. 10.)

Velocities, as ſuch, but in Virtue of them, and the Quantities of Matter taken together, or becauſe the Squares of the Velocities is the ſame Thing with the ſimple Velocities multiplied by the Quantities of Matter. Therefore when it is ſaid, the Forces of Fluids are as the Squares of the Velocities, that Part of the Force which ariſes from the Quantity of Matter is really taken into Conſideration. How ridiculous then muſt it be in thoſe Gentlemen to fetch an Argument from hence to prove, that the Forces of Bodies in Motion are as the Squares of the Velocities and Quantities of Matter too, when they are as the Squares of the Velocities, only becauſe the Quantities of Matter are implied in them.

* From this Propoſition is deduced the Method of computing the Power of a Machine, which is to be moved by Wind or Water, &c. See an Inſtance of ſuch a Calculation in the Memoirs of the Royal Academy of Sciences for the Year 1725.

In the midſt of this Hole, and conſequently in the Stream, let us ſuppoſe a Plane as PQ ſuſpended, but ſomewhat leſs than is ſufficient to fill the Hole, leſt it ſtop the Current of the Water. Now, 'tis certain, this Plane ſupports a Column of the Fluid, equal to that which preſſes upon any other Part of the Bottom of the Veſſel of equal Dimenſions with itſelf (for being thus placed it may be looked upon as a Part of the Bottom) but every Part bears a Column, whoſe Baſe is equal to its own Dimenſions, and its Height the ſame with that of the Surface of the Fluid in the Veſſel: Conſequently this Plane ſupports ſuch a Column, that is, it is reſiſted by the Stream with a Force equal to the Weight of a Column, whoſe Baſe has the ſame Dimenſions with itſelf, and whoſe Height is equal to that of the Surface of the Fluid in the Veſſel, that is, ſuch an Height as a Body by falling freely from, would acquire a Velocity equal to that with which the Fluid moves.

XIII. The Preſſure of a Fluid againſt a perpendicular Bank or Sluice, *&c.* is equal to the Weight of a Column of the ſame Fluid, whoſe Baſe is equal to ſo much of the Bank as is below the Surface of the Fluid, and whoſe Height is equal to half the Depth of the Fluid *.

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* From hence we ſee the Reaſon, why the Water of the Sea or great Lakes is as eaſily kept within their Banks (ſetting aſide the Force which ariſes from the Motion of the Waves, *&c.*

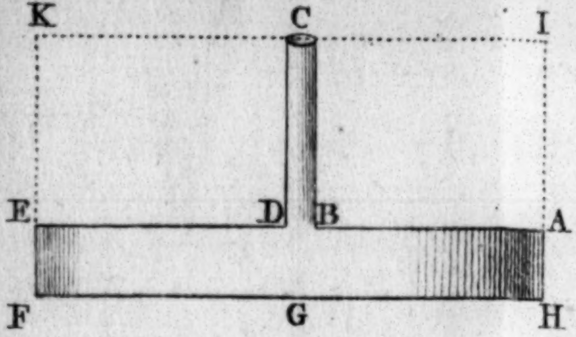
If the Preſſure upon every Part of the Bank from the Surface to the Bottom, was as great as it is at the Bottom, the Preſſure againſt it would be equal to the Weight of a Column, whoſe Baſe is equal to ſo much of the Bank as is under the Surface of the Fluid, and which has the *whole* Depth of the Fluid for its Height; for the Preſſure upon every Part of the Bank at the Bottom is equal to the Weight of a Column, whoſe Baſe correſponds to the Part preſſed upon, and whoſe Height is that of the Depth of the Fluid; conſequently if the Preſſure was the ſame every where from Top to Bottom, it would be equal to the Weight of as many ſuch Columns as would anſwer to all the Parts of the Bank: But the Preſſure every where diminiſhes in Proportion as we approach the Top, where it is Nothing; it is therefore but *half* * what it would be in the other Caſe; from whence the Propoſition is clear.

&c.) as that of the narroweſt Canal, *viz.* becauſe the Preſſure of Fluids is not in Proportion to their Surfaces, but their Depths, and the Surfaces they preſs againſt.

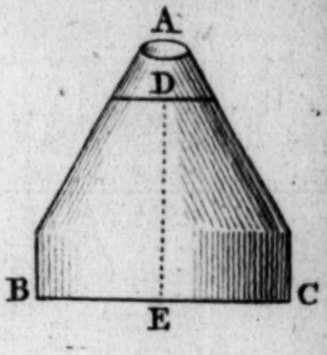
* Becauſe the Sum of a Number of Terms in Arithmetical Progreſſion beginning from Nothing, is half the Sum of an equal Number of Terms, each of which is equal to the laſt in the Progreſſion.

Part II. Plate II. p.26

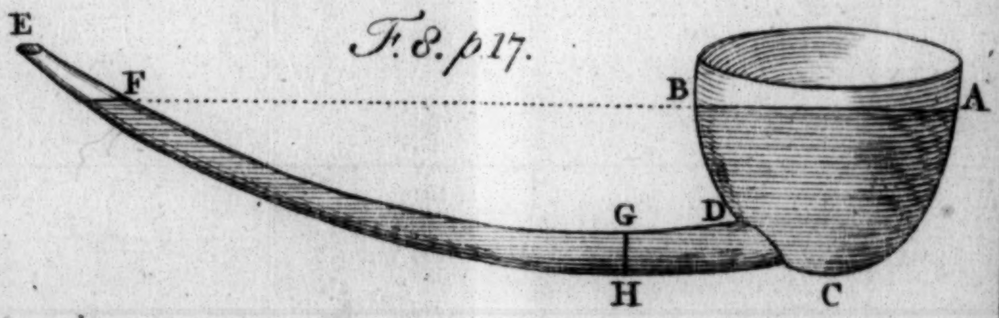
F.7. p.18.



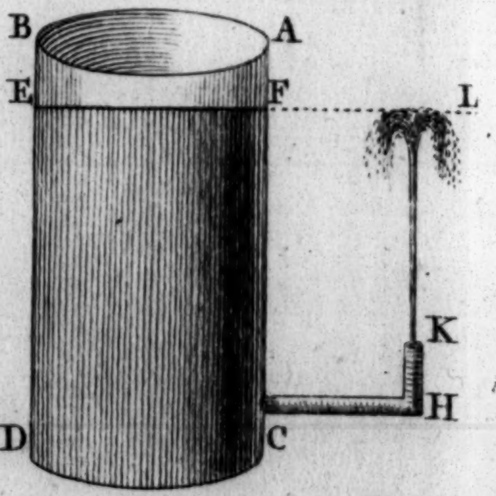
F.6. p.17.



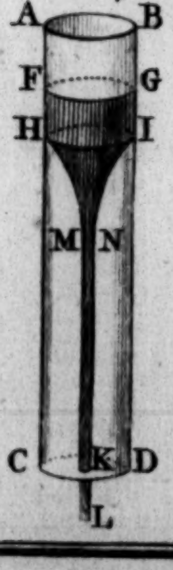
F.8. p.17.



F.10. p. 21.



F.9. p.20.



CHAP. II.

Of the Effects Fluids have on Solids immerſed therein.

I. THE *Specific* Gravity of a Body is that by which it is ſaid to be heavier, or lighter than another of a different Kind: Thus Lead is ſaid to be ſpecifically heavier than Cork; becauſe ſuppoſing an equal Bulk of each, the one would be heavier than the other. From hence it follows, that a Body, ſpecifically heavier than another, is alſo more denſe, that is, contains a greater Quantity of Matter under the ſame Bulk, becauſe Bodies weigh in Proportion to the Quantities of Matter they contain (Part I. Chap. 3. §. 7.)

II. If a Solid be immerſed in a Fluid of the ſame ſpecific Gravity with itſelf, it will remain ſuſpended therein, in whatever Part of the Fluid it is put.

Let the Body FGHI (*Fig.* 12.) be immerſed in the Fluid ABCD to the Depth MN, or any other whatever; I ſay, it will continue in the ſame Part of the Fluid, when left to itſelf, without either riſing towards the Surface, or ſinking towards the Bottom.

For, the Body being (by the Suppoſition) of equal Gravity with the Fluid, the Weight of the Column KLHI, which conſiſts partly of

Fluid, and partly of the Body, is the ſame as if it had been all Fluid; conſequently HI, that Part of the Surface of the Stratum MN, which lies immediately under the Body, is preſſed with the ſame Degree of Force, that any other Part of the ſame Dimenſions is, and therefore the whole Column KLHI will be ſupported in its Place. Now, the ſame being true of the Column KLHI, whatever be its Length, 'tis evident the Body will be ſuſpended in its Place at any Depth.

III. But if the Body is ſpecifically heavier than the Fluid, in which it is immerſed, it will ſubſide to the Bottom: For then, in whatever Part of the Fluid it is put, the Column KLHI will always be heavier than an equal Column, that conſiſts all of Fluid; conſequently HI, that Part of the Stratum MN, which lies immediately under the Body, will ſuffer a greater Preſſure, than any other Part of the ſame Dimenſions; and therefore will give way, and permit the Body to ſubſide continually, till it reaches the Bottom.

IV. On the contrary, if the Body is ſpecifically lighter than the Fluid, it will riſe to the Top, in what Part of the Fluid ſoever it is put. For then, the Column KLHI will always be lighter than an equal Column which is all Fluid; conſequently HI will be leſs preſſed downwards, than any other Part of the ſame Stratum of equal Dimenſions, and will therefore continually riſe up, carrying the Body with it, till it arrives at the Top.

V. A Body, being laid on the Surface of a Fluid ſpecifically heavier than itſelf, ſinks into it, till the immerſed Part takes up the Place of a Quantity of Fluid, whoſe Weight is equal to that of the whole Body.

Let EFGH (*Fig.* 13.) be a Body, floating on a Liquor ſpecifically heavier than itſelf, it will ſink into it, till the immerſed Part IKGH takes up the Place of ſo much Fluid as is equal to it in Weight. For, in that Caſe, GH, that Part of the Surface of the Stratum upon which the Body reſts, is preſſed with the ſame Degree of Force, as it would be, was the Space IKGH full of the Fluid; that is, all the Parts of that Stratum are preſſed alike, and therefore the Body, after having ſunk ſo far into the Fluid, is in *Æquilibrio* with it, and will remain at Reſt.

From hence it follows, that a Body is as much ſpecifically lighter, than the Fluid on which it floats, as the immerſed Part is leſs than the Whole. For, by how much the leſs the immerſed Part is, ſo much the leſs Fluid is equal in Weight to the whole Body; that is, the Body is ſo much the lighter in Reſpect of the Fluid. And, if the ſame Body be made to float ſucceſſively in Fluids, whoſe ſpecific Gravities differ among themſelves, (but all exceed that of the Body,) the lighter the Fluids are, ſo much greater will be the Part immerſed *.

VI. A Body, ſuſpended in a Fluid ſpecifically lighter than itſelf, loſes a Part of its Weight (or rather communicates it to the Fluid) equal to that of a Quantity of Fluid of the ſame Bulk.

Let us, inſtead of ſuppoſing the Body ſuſpended in the Fluid, imagine it to be away, and its Place filled with the Fluid; now 'tis evident, this being of the ſame ſpecific Gravity with the circumjacent Fluid, will be entirely ſupported by it, or, if we ſuppoſe the Body to be of the ſame ſpecific Gravity with the Fluid, it will be wholly ſuſpended by it; we ſee therefore the Preſſure of the circumambient Fluid, whereby it endeavours to buoy up the Body, is equivalent to the Weight of ſo much Fluid, as would fill the Place the Body takes up. But, ſince the Fluid preſſes only on the Surface of the Body, that Preſſure is the ſame, whatever be the ſpecific Gravity of the Body; the Body therefore loſes ſo much of its Weight, as the Fluid would naturally buoy up; that is, ſo much, as is the Weight of a Quantity of Fluid of the ſame Bulk.

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* This Phænomenon is what gave riſe to the Hydrometer, an Inſtrument of great Uſe in aſcertaining the Genuineneſs of Liquors; for it rarely happens, that the adulterated and the genuine Liquor (however they may agree in Appearance) are of the ſame ſpecific Gravity.

This Propoſition affords us a Method of determining the Relation, which the ſpecific Gravities of Bodies, whether Fluid or Solid, bear to each other. For, whereas by weighing a Solid in a Fluid ſpecifically lighter than itſelf, we find the abſolute Weight of a Quantity of the Fluid equal to it in Bulk (*viz.* the Weight the Solid loſes) the Relation, that Weight bears to the Weight of the Solid, is the Relation of their ſpecific Gravities; becauſe the Weights of Bodies, whoſe Bulks are equal, are as their ſpecific Gravities: conſequently, if the ſame Solid is weighed ſucceſſively in different Fluids (all lighter than itſelf) we gain the Relation, which the ſpecific Gravity of each bears to that of the Solid, and therefore to one another. Again, if different Solids are weighed in the ſame Fluid, the Relation, which the ſpecific Gravity of that Fluid bears to each Solid, is had, and therefore alſo the ſpecific Gravities of the Solids among themſelves *.

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* Upon this is founded the Uſe of the Hydroſtatical Balance for determining the ſpecific Gravities both of Solids and Fluids. The Practice is thus. Firſt, let the Solid be weighed in Air, that is, out of the Fluid; afterwards in it (this ought to be done by ſuſpending it at one End of the Balance by a String, that is as nearly of the ſame ſpecific Gravity with the Fluid made Uſe of as poſſible, and letting it ſink into the Fluid till it is wholly immerſed below the Surface; if the Fluid is Water, an Horſe-Hair is moſt convenient to hang the Body at the End of the Balance by) then ſubſtract its Weight in the Fluid from its Weight in Air, the Difference is what it loſes in

CHAP. III.

Of the Air.

I. THAT Part of Natural Philoſophy, which treats of the Properties of the *Air*, and the Effects of its *Preſſure* and *Elaſticity*, is called *Pneumatics*.

II. Air is a thin tranſparent elaſtic Fluid ſurrounding the Earth to a certain Height, and taken all together, is called the *Atmoſphere*.

III. That Air is a Fluid, is evident from the eaſy Paſſage it affords to Bodies moving in it: For this ſhews it to be a Body, whoſe Parts eaſily yield to a Preſſure, that is greater on one Side than on the other, which is the Definition of a Fluid.

IV. Air gravitates towards the Earth, or is heavy like other Bodies.

To prove this, we have Abundance of Arguments both from Senſe and Experiment. Thus, when the Hand is applied to the Orifice of a Veſſel, it readily perceives the Weight of the incumbent Atmoſphere, as ſoon as the

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the Fluid. This done, ſay, by the Rule of Proportion, as the Weight loſt in the Fluid is to its Weight in Air, ſo is Unity, or any Number taken at Pleaſure, to a Fourth, which by its Relation to the former, will expreſs the Relation of ſpecific Gravity of the Solid to that of the Fluid. Thus, the Relation, which the ſpecific Gravity of the ſame Fluid bears to that of various Solids, or of the ſame Solid to that of various Fluids, and conſequently the Relation of the ſpecific Gravities of all among themſelves may be obtained.

Air included in the Veſſel begins to be drawn out. Thus, Glaſs-Veſſels exhauſted of their Air (if not ſtrong enough to ſuſtain the Preſſure of the incumbent Atmoſphere) are cruſhed to Pieces by the Weight of the Air without. When the Air is exhauſted out of a Veſſel, the Veſſel weighs leſs than before. With a great many more Experiments generally mentioned by Authors on this Subject *.

V. The exact Weight of the incumbent Air is determined by filling a Tube with Mercury, and immerging the open End in a Veſſel of the ſame Fluid: For then the Mercury will run down the Tube, till its Surface is fallen to the perpendicular Height of about twenty-nine or thirty Inches above the Surface of the Mercury in the Veſſel, and no further: if the ſame Experiment is made with Water, the Surface of it will ſtand at about the Height of thirty-two Feet above the Surface of that in the Veſſel; the Column of Mercury in one Caſe, and the Column of Water in the other, exactly balancing the Weight of a Column of Air, which reaches to the Top of the Atmoſphere, and preſſes upon the Surface of the Fluid in the Veſſels. This is what is called the Torricellian Experiment, from TORRICELLI the Inventor, and is the ſame with the common Barometer.

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* See *Boyle's* Tracts, or *Graveſande*, Lib. II. P. III.

From hence it follows (Chap. I. §. 9.) that all Bodies, at the Surface of the Earth, ſuſtain as great a Weight from the Preſſure of the Air, as is that of a Column of Water, whoſe Height is thirty-two Feet, and its Baſe equal to the Surface of the Body preſſed upon*.

VI. That the Suſpenſion of the Mercury in the Barometer depends on the Preſſure of the external Air, is beyond all doubt; for if the Barometer is included in the Air-Pump, the Mercury falls in the Tube, in Proportion as the Air is exhauſted out of the Receiver; and if the Air is let in again gradually, the Mercury reaſcends proportionably, till it reaches its former Height.

VII. That the Atmoſphere is extended to a determinate Height, appears from hence; *viz.* that when the Torricellian Tube is removed to a more elevated Place, the ſuſpended Column of Mercury becomes ſhorter; which is, becauſe a ſhorter Column of Air preſſes upon it; or, that the Tube, in this Situation, is nearer the Top of the Atmoſphere.

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* The Preſſure of the Atmoſphere upon every ſquare Inch, near the Surface of the Earth, is about fifteen Pounds, being equal to the Weight of a Column of Mercury, whoſe Height is thirty Inches, and its Baſe one ſquare Inch. For, ſuch a Column of Mercury would weigh about fifteen Pounds. The Weight of the Atmoſphere therefore, which preſſes upon a Man's Body, is equal to ſo many Times fifteen Pounds, as the Surface of his Body contains ſquare Inches.

The Reaſon why a Perſon ſuffers no Inconvenience from ſo great a Preſſure, is owing to the Air included within the Pores and Fluids of the Body, which by its Reaction is a Counterpoiſe to the Preſſure of the external Air.

VIII. The Elaſticity of the Air is that Property by which it contracts itſelf into leſs Space, when an additional Preſſure is laid upon it; and recovers its former Dimenſions, when the Preſſure is taken off. This is accounted its diſtinguiſhing Property, all the reſt being common to it with other Fluids.

Of this we have numerous Proofs. Thus, a Bladder full of Air being compreſſed by the Hand, the included Air gives way; but when the Preſſure is taken off, the Air expands itſelf, and readily fills up the Cavity, or Impreſſion made in the Surface of the Bladder. And, if a larger Quantity of Air, than is naturally preſſed into a Veſſel by the Weight of the incumbent Atmoſphere, is forced into it by the *Condenſer* (an Engine for that purpoſe) and if that Air is afterwards let out by opening the Veſſel, the Remainder is found to be of the ſame Weight as at firſt; from whence it follows, that the Air, by means of its Elaſticity or Spring, drives out all that which was forced in by the Condenſer, recovers its former Dimenſions, and fills the Veſſel as before.

IX. From hence, together with what has been obſerved about the Preſſure of the Atmoſphere, it follows, that the Air near the Surface of the Earth, is compreſſed into a much narrower Space by the Weight of the

Air above, than that which it would naturally take up, was it free from that Preſſure; accordingly it is found by Experiment, that, when the Preſſure of the Atmoſphere is taken off from any Portion of the Air, it immediately expands itſelf into a vaſt Extent. Hence it is, that thin Glaſs Bubbles or Bladders filled with Air, being included in the Receiver of the Air-Pump, are broke in Pieces by the Spring of the Air, which they contain within them, when the Preſſure of the external Air is taken off. Thus, a Bladder quite flaccid, containing only a ſmall Quantity of Air in it, ſwells upon the Removal of the external Air, and appears diſtended, as if it contained as great a Quantity as poſſible. The ſame Effect is found in carrying a Bladder ſomewhat flaccid to a more elevated Place, for there the external Preſſure being leſs, the Air included in the Bladder is in ſome Meaſure free from the Preſſure of the Atmoſphere; it therefore dilates itſelf, and diſtends the Bladder as in the former Caſe.

X. It is found by Experiment, that the Quantity of Space into which Air may be contracted by Preſſure, is reciprocally proportionable to the compreſſing Force. From whence it follows, that the Denſity of the Air is proportionable to the Preſſure which it ſuſtains; becauſe the leſs the Space is, into which a given Quantity of it is contracted, the denſer it is. As to the utmoſt Degrees of Expanſion and Contraction, which the Air is capable of, they are as yet unknown. In ſeveral Experiments made by Mr. BOYLE, Air in its natural State, that is, preſſed only with the Weight of the incumbent Atmoſphere, dilated itſelf, when that Preſſure was taken off, into more than thirteen thouſand Times the Space it took up before. And, he was able ſo far to compreſs it, that it ſhould take up more than five hundred and twenty thouſand Times leſs Space than that, into which it would dilate itſelf, when free from its Preſſure *.

XI. From this Property it follows, that the Air in the inferior Parts of the Atmoſphere is more denſe than that, which is at great Heights in the ſame; or, that the Denſity of the Air decreaſes continually, as we approach the Top of the Atmoſphere. For the Denſity of the Air is proportionable to the Force

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* See *Boyle*'s Tracts and Experiments on the Spring and Preſſure of the Air.

Various have been the Opinions of Philoſophers concerning the Cauſe of this prodigious Spring in the Particles of Air; ſome holding it to depend on their Figure, which they ſuppoſe to reſemble in ſome Manner little Bundles of Twigs, or the Branches of Trees; ſome think them like Fleeces of Wool, others conceive them as rolled up like Hoops, or the Springs of Watches, and endeavouring to expand themſelves by Virtue of their Texture. But Sir *Iſaac Newton* is of Opinion, that ſuch a Texture is by no Means ſufficient to account for that vaſt Power of Expanſion obſerved above; but that each Particle is endued with a repelling Force which encreaſes as they approach one another, and accordingly keeps them aſunder at Diſtances reciprocally proportionable to the Preſſure they ſuſtain.

See *Hales*'s Statical Eſſays. Vol. I. Chap. 6.

with which it is compreſſed, and that Force continually decreaſes, as we approach the Top.

Was the Denſity of the Atmoſphere every where the ſame as it is near the Surface of the Earth, its Height (as is computed from the Quantity of Preſſure it exerts in raiſing the Mercury in the Barometer) would be about five Miles. But whereas its Denſity continually decreaſes, as we approach the Top, and it is uncertain how far the Particles may expand themſelves, where there is little or no Preſſure, the true Height cannot be obtained. It is computed to continue of a ſenſible Denſity to the Height of about forty-five, or fifty Miles.

XII. The Elaſticity of the Air produces the ſame Effects with its Preſſure.

For, Action being equal to Reaction, the Force, which the Spring of the Air exerts in endeavouring to expand itſelf, is equal to the Force with which it is compreſſed; juſt as it is in the Spring of a Watch, which exerts no Force, but in Proportion as it is wound up; conſequently a Quantity of Air in ſuch a State of Contraction, as it would be compreſſed into by the Weight of the incumbent Atmoſphere, exerts a Force equal to that Weight. If a Quantity of Air therefore is included in a Veſſel, and is of the ſame Denſity with the circumambient Air, its Preſſure againſt the Sides of the Veſſel is equal to the Weight of the Atmoſphere. Thus, Mercury is ſuſtained to the ſame Height by the elaſtic Force of Air included in a Glaſs Veſſel, no Way communicating with the external Air, as by the Weight of the Atmoſphere itſelf.

XIII. The Elaſticity of the Air is augmented by Heat, and diminiſhed by Cold *. For if a Bladder, which is about half filled with Air, is laid before the Fire, it will, when it is ſufficiently heated, be diſtended and burſt. Thus, Glaſs Bubbles being laid upon the Fire immediately burſt with great Violence by the augmented Spring of the included Air.

XIV. The Denſity of the Air thus continually varying, according to the different Degrees of Heat and Cold, to which it is expoſed, makes it difficult to aſcertain its true ſpecific Gravity. RICCIOLUS eſtimates it to be to that of Water, as one to a Thouſand: MERSENNUS, as one to one Thouſand, three Hundred: Mr. BOYLE,

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* This Property is found in all Bodies both Solid and Fluid, but in a much leſs Degree, than it is in Air. Thus, if a Flaſk be filled with Water, only to the lower Part of the Neck, and is then ſet upon the Fire, the Water, when it begins to grow warm, will riſe into the Neck, and continue to aſcend, as the Heat is increaſed. And when a Wire or Bar of Iron is heated, it is augmented both in Length and Diameter.

Upon this Property depends the Phænomena of the Thermometer, which is a Glaſs Bubble with a ſmall hollow Stem ariſing from it. This Bubble and Part of the Stem is uſually filled with Mercury, or Spirit of Wine, which will riſe or fall in the Stem, as they are affected by the Heat or Cold of the external Air. If a ſufficient Degree of Heat is ſuddenly applied to this Inſtrument, the Liquor is obſerved to deſcend a little before it riſes, becauſe the Glaſs diſtending itſelf, the Capacity of the Bubble is augmented, before the included Liquor is affected by the Heat.

BOYLE, by more accurate Experiments, found it to be, as one to nine Hundred and Thirty eight; and thinks, that all Things conſider'd, the Proportion of one to a Thouſand may be taken as a Medium; for there is no fixing any preciſe Proportion, becauſe not only the ſpecific Gravity of Air, but that of Water alſo, is continually varying. However, by ſome Experiments made ſince with more Accuracy before the *Royal Society*, the Proportion has been fixed at about one to eight Hundred and Eighty.

XV. Air is neceſſary for the Preſervation of Animal and Vegetable Life: neither will Fire ſubſiſt without it. The Reaſon of this is as yet unknown to Philoſophers. Mr. HALES by ſeveral curious Experiments in his Statical Eſſays makes it probable, that 'tis owing to its Elaſticity *.

CHAP. IV.

Of the Reſiſtance of Fluids.

THE Reſiſtance a Body meets with in moving through a Fluid, is of three Kinds. The firſt ariſes from the Friction of the Body againſt the Particles of the Fluid; the ſecond from their Coheſion or Tenacity among themſelves; the third, from their Inactivity, or the Tendency they have in common with other Bodies, to keep the Places they poſſeſs.

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* See his *Analyſis* of it. Statical Eſſays, Vol. I. Chap. 6.

The firſt, *viz.* that which ariſes from the Friction of the Body againſt the Particles of the Fluid, is very inconſiderable; for whatever the Weight is, which preſſes the Particles of a Fluid together, the Freedom, with which a Body moves through it, is not ſenſibly diminiſhed thereby. As was obſerved, Chap. I. §. 2. in the Notes.

The ſecond, or that which ariſes from the Tenacity of the Particles of the Fluid, is as the Time the Body continues paſſing in it*;

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* We have a very curious Argument in Confirmation of this, and which at the ſame Time illuſtrates the Manner in which a Body makes its Way through a tenacious Fluid, by Sir *Iſaac Newton* himſelf, in a Poſtſcript to a Letter in the Philoſophical Tranſactions, No. 371. It is as follows. ‘ Suppoſe Pieces of ‘ fine Silk, or the like thin Subſtance, extended in parallel ‘ Planes, and fixed at ſmall Diſtances from each other. Suppoſe ‘ then a Globe to ſtrike perpendicularly againſt the Middle of ‘ the outermoſt of the Silks, and by breaking through them to ‘ loſe Part of its Motion. If the Pieces of Silk be of equal ‘ Strength, the ſame Degree of Force will be required to break ‘ each of them; but the Time, in which each Piece of Silk re‘ ſiſts, will be ſo much ſhorter as the Globe is ſwifter; and the ‘ Loſs of Motion in the Globe conſequent upon its breaking ‘ through each Silk, and ſurmounting the Reſiſtance thereof, ‘ will be proportional to the Time in which the Silk oppoſes it‘ ſelf to the Globe's Motion; inſomuch that the Globe by the ‘ Reſiſtance of any one Piece of Silk, will loſe ſo much leſs of ‘ its Motion as it is ſwifter. But on the other Hand, by how ‘ much ſwifter the Globe moves, ſo many more of the Silks it ‘ will break through in a given Space of Time; whence the ‘ Number

Thus, ſuppoſe a Body continues to move within a Fluid for the Space of one Hour; if its Motion be very quick during that Time, it then moves a great Way in that Fluid, and conſequently meets with a great deal of the Fluid to reſiſt it; but is reſiſted the leſs in each Part thereof in Proportion to the Stay it makes there: whereas, if its Motion be ſlow, it then moves but a little Way in that Time, but is reſiſted ſo much the longer in each Part thereof. So that whether the Body moves faſt or ſlow, the Reſiſtance it ſuffers is the ſame; and depends therefore on Nothing but the Time we ſuppoſe it to continue moving within the Fluid. This Species of Reſiſtance is alſo very ſmall, except in glutinous and viſcid Fluids, whoſe Parts are not eaſily ſeparated.

‘ Number of the Silks, which oppoſe themſelves to the Motion of the Globe in a given Time, being reciprocally proportional to the Effect of each Silk upon the Globe, the Reſiſtance made to the Globe by theſe Silks, or the Loſs of Motion the Globe undergoes by them in a given Time, will be always the ſame.

‘ Now, if the Tenacity of the Parts of Fluids obſerves the ſame Rule, as the Coheſion of the Parts of theſe Silks; namely, that a certain Degree of Force is required to ſeparate and diſunite the adhering Particles, the Reſiſtance ariſing from the Tenacity of Fluids muſt obſerve the ſame Rule, as the Reſiſtance of the Silks; and therefore in a given Time, the Loſs of Motion a Body undergoes in a Fluid by the Tenacity of its Parts, will in all Degrees of Velocity be the ſame; or in fewer Words, that Part of the Reſiſtance of Fluids, which ariſes from the Coheſion of their Parts, will be uniform.’

The third Species is the principal Reſiſtance, that Fluids give to Bodies, and ariſes from their Inactivity, or the Tendency the Particles, of which they conſiſt, have to continue at Reſt. The Quantity of this Reſiſtance depends on the Velocity the Body moves with on a double Account: For, in the firſt Place, the Number of Particles put into Motion by the moving Body in any determinate Space of Time, is proportionable to the Velocity wherewith the Body moves; and in the next Place, the Velocity with which each of them is moved, is alſo proportionable to the Velocity of the Body; this Species therefore of Reſiſtance is in a duplicate Proportion, or as the Square of the Velocity, with which the Body moves through the Fluid *.

II. Farther, the Reſiſtance a Body moving in a Fluid meets with from thence, may be conſidered with Regard to the Fluid; and then it will be found to be more or leſs, ac-

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* This may be otherwiſe demonſtrated from the twelfth Section of the firſt Chapter; for from thence it follows, that the Reſiſtance a Fluid gives to a Solid againſt which it moves, is proportionable to the Height a Body muſt fall from, to acquire ſuch a Degree of Velocity as the Fluid moves with: But the Heights Bodies fall from are as the Squares of the Velocities they acquire by falling; conſequently the Reſiſtance a Fluid gives to a Solid, againſt which it moves, is alſo as the Square of its Velocity. Now it matters not, as to the Reſiſtance, whether the Fluid moves againſt the Solid, or whether it be at Reſt, and the Solid moves in it; the Reſiſtance therefore which a Fluid gives to a Solid moving in it, is as the Square of the Velocity, with which it moves.

cording to the Denſity of the Fluid. For by how much denſer the Fluid is, ſo much the greater Number of Particles are to be put into Motion by the Body, in Order to make its Way through it.

III. The next Thing to be conſidered, is the Effects of the Reſiſtance of Fluids upon Bodies moving in them; that is, the Retardation, which they cauſe in the Motion of a Body by their Reſiſtance, or the Quantity of Motion they deſtroy.

And this, in ſimilar Bodies of equal Magnitudes, is inverſely as their Denſities, or the Quantity of Matter they contain; for by how much the greater the Quantity of Matter in any Body is, ſo much the more eaſily does it overcome the Reſiſtance it meets with from the Fluid. Thus we ſee the Reſiſtance of the Air has a much leſs Effect in deſtroying the Motion of an heavy Body, than of a light one which has the ſame Dimenſions.

IV. In ſimilar Bodies of equal Denſities, but different Magnitudes, the Retardation is inverſely as their homologous Sides. For the Reſiſtance Bodies meet with in a Fluid, is inverſely as the Quantities of Matter they contain (by the laſt) that is inverſely as the Cubes of their homologous Sides; and it is alſo directly as their Surfaces, becauſe 'tis by them that they move the Fluid out of its Place; that is, directly as the Squares of their homologous Sides;

conſequently the Retardation is inverſely as their homologous Sides[*].

Having given the fundamental Principles of *Hydroſtatics*, and ſhewn how Fluids, both compreſſible and incompreſſible, are diſpoſed to act upon each other, and upon Solids by their Preſſure, Motion, Elaſticity, and Reſiſtance; I proceed now to account for ſome of the more remarkable Phænomena of Nature, in which they are in Part, or altogether concerned: And this I deſign for the Subject of the following Diſſertations.

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[*] Becauſe the inverſe Ratio of the Cubes of any Numbers being compounded with the direct Ratio of the Squares of the ſame, gives the inverſe Ratio of the Numbers themſelves.

DISSERTATION I.

Of Sound.

WHEN the Parts of an elaſtic Body are put into a tremulous Motion, by Percuſſion, or the like; ſo long as the Tremors continue, ſo long is the Air, included in the Pores of that Body, and likewiſe that which preſſes upon its Surface, affected with the like Tremors and Agitations: Now, the Particles of Air being ſo far compreſſed together by the Weight of the incumbent Atmoſphere, as their repulſive Forces permit,(as has been explained, Chap. 3.) it follows, that thoſe, which are immediately agitated by the reciprocal Motions of the Particles of the elaſtic Body, will, in their Approach towards thoſe which lie next them, impel them alſo towards each other; and thereby cauſe them to be more condenſed, than they were by the Weight of the incumbent Atmoſphere, and in their Return will ſuffer them to expand themſelves again; whereby the like Tremors and Agitations will be propagated to them; and ſo on, till having arrived at a certain Diſtance from the Body, the Vibrations ceaſe, being gradually deſtroyed by a continual ſucceſſive Propagation of Motion to freſh Particles of Air throughout their Progreſs.

Thus it is that Sound is communicated from a tremulous Body to the Organ of Hearing. Each Vibration of the Particles of the ſounding Body is ſucceſſively propagated to the Particles of the Air, till it reaches thoſe which are contiguous to the *Tympanum* of the Ear, (a fine Membrane diſtended acroſs it,) and theſe Particles in performing their Vibrations impinge upon the Tympanum, which agitates the Air included within it; and that being put into a like tremulous Motion, affects the auditory Nerve, and thus excites in the Mind the Senſation or Idea of what we call *Sound*.

Now ſince the repulſive Force of each Particle of Air is equally diffuſed around it every Way; it follows, that when any one approaches a Number of others, it not only repels thoſe which lie before it, in a right Line; but the reſt, laterally, according to their reſpective Situations: that is, it makes them recede every Way from itſelf, as from a Center: and, this being true of every Particle, it follows, that the aforeſaid Tremors will be propagated from the ſounding Body in all Directions, as from a Center: And farther, if they are confined for ſome Time from ſpreading themſelves by paſſing through a Tube or the like, will, when they have paſſed through it, ſpread themſelves from the End in every Direction. In like Manner, thoſe which paſs through an Hole in an Obſtacle they meet with in their Way, will afterwards ſpread themſelves from thence, as if that was the Place where they began; ſo that the Sound, which paſſes through an Hole in a Wall, or the like, is heard in any Situation whatever, that is not at too great a Diſtance from it. Something analogous to this we may obſerve in the Motion of Waves upon the Surface of a Fluid, which are propagated equally through all Parts of the Surface in a Circle, though occaſioned not by a circular, but reciprocal Motion and Agitation of the Finger, or any other Body in a ſtraight Line.

Since the repulſive Force, with which the Particles of Air act upon each other, is reciprocally as their Diſtances; (Chap. 3. §. 10.) it follows, that when any Particle is removed out of its Place by the Tremors of a ſounding Body, or the Vibrations of thoſe which are contiguous to it, it will be driven back again by the repulſive Force of thoſe towards which it is impelled, with a Velocity proportionable to the Diſtance from its proper Place; becauſe the Velocity will be as the repelling Force. The Conſequence of this is, that, let the Diſtance be great or ſmall, it will return to its Place in the ſame Time; (for the Time a Body takes up in moving from Place to Place will always be the ſame, ſo long as the Velocity it moves with is proportionable to the Diſtance between the Places.) The Time therefore in which each Vibration of the Air is performed, depends on the Degree of Repulſion in its Particles: And ſo long as that is not altered, will be the ſame at all Diſtances from the tremulous Body; conſequently, as the Motion of Sound is owing to the ſucceſſive Propagation of the Tremors of a ſounding Body through the Air, and as that Propagation depends on the Time each Tremor is performed in, it follows, that the Velocity of Sound varies as the Elaſticity of the Air, but continues the ſame at all Diſtances from the ſounding Body.

And as the Velocity, with which Sound is propagated, depends on the Elaſticity of the Air, ſo it does alſo on its Denſity; for when the Denſity of the Air is augmented, while its Elaſticity remains the ſame *, a great Number of Particles will move forwards and backwards in each Vibration; now, ſince we ſuppoſe the Cauſe by which they put each other into

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* Perhaps it will not appear to every one, how the Denſity of the Air can be augmented without a proportional Increaſe of its Elaſticity; becauſe, *cæteris paribus*, the nearer the Particles approach each other, the ſtronger is the Action of their repulſive Force.

But it is to be conſidered, that when the Air becomes colder, its Elaſticity is diminiſhed, and then the Particles are brought cloſer together by the Preſſure of the Atmoſphere, till they acquire an Elaſticity equal to what they had before; *viz.* ſuch as anſwers to the Preſſure they ſuſtain (Chap. 3. §. 12.) From hence we may infer, that the Propagation of Sound is ſlower in Winter than in Summer, when the Mercury in the Barometer is at the ſame Height; for the Preſſure of the Air being the ſame, its Elaſticity which depends upon it, is ſo too; but the Air is denſer by Reaſon of the Cold, and therefore its Vibrations ſlower.

into Motion (*viz.* their Elaſticity,) the ſame, they will each receive a leſs Degree of Velocity; and ſo the Vibrations will be performed in a longer Time, whence the Succeſſion of them will be ſlower, and the Progreſs of the Sound proportionably retarded *.

Whereas the undulatory Motion of the Air, which conſtitutes Sound, is propagated in all Directions from the ſounding Body; it will frequently happen, that the Air, in performing its Vibrations, will impinge againſt various Objects, which will reflect it back, and ſo cauſe new Vibrations the contrary Way; now, if the Objects are ſo ſituated, as to reflect a ſufficient Number of Vibrations back (*viz.* ſuch as proceed different Ways) to the ſame Place, the Sound will be there repeated, and is called an *Echo*[*]. And, the greater the Diſtance of the Objects is, the longer will be the Time, before the Repetition is heard. And when the Sound in its Progreſs meets with Objects, at different Diſtances, ſufficient to produce an Echo, the ſame Sound will be repeated ſeveral Times ſucceſſively, according to the different Diſtances of thoſe Objects from the ſounding Body; which makes what is called a *repeated* Echo.

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* The Method of determining the Velocity with which Sound is propagated, is (by the Help of a ſhort Pendulum) to eſtimate the Time, which paſſes between ſeeing the Fire of a Gun at a Diſtance, and hearing the Report. Its great Velocity makes it difficult to be determined exactly; accordingly Authors differ much in their Accounts. The moſt accurate Obſervers, Dr. *Halley* and Dr. *Durham*, have found it to be about one Thouſand one Hundred and Forty-two Feet, which is almoſt a Quarter of a Mile, in a Second.

The uſual Experiments to prove that the Air is neceſſary for the Propagation of Sound, are ſuch as theſe. A ſmall Bell being put into the Receiver of the Air-Pump, may be heard at a conſiderable Diſtance before the Air is exhauſted out of it; but when the Air is much rarefied by exhauſting, can ſcarcely be heard at all. When the Air is condenſed, the Sound is augmented in Proportion to the Condenſation. Theſe Experiments do not only ſucceed in forced Rarefactions and Condenſations, but in ſuch alſo as are Natural; Sound being obſerved to be much weaker on the Tops of high Mountains, where the Air is leſs condenſed by the Weight of the incumbent Atmoſphere, than in the Valleys below.

If the Vibrations of the tremulous Body are propagated through a long Tube, they will be continually reverberated from the Sides of the Tube into its Axis, and by that means prevented from ſpreading, till they get out of it; whereby they will be exceedingly encreaſed, and the Sound rendered much louder than it would otherwiſe be[†].

The Difference of *Muſical* Tones depend on the different Number of Vibrations communicated to the Air, in a given Time, by the

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[*] In *Woodſtock* Park, near *Oxford*, there is an Echo, which repeats diſtinctly ſeventeen Syllables by Day, and twenty by Night. See *Plot*'s Natural Hiſtory of *Oxfordſhire*.

The Reaſon why it repeats more Syllables by Night, than by Day, is becauſe the Air, being colder at that Time, is more denſe; and therefore the Return of the firſt Vibrations being ſlower, gives Time for the Repetition of more Syllables.

[†] This is the Caſe in the *Stentorophonic* Tube or Speaking-Trumpet. See *Kircher* de Re Muſica. Lib. 9. Par. 3. *Ode* Philoſ. Natur. Princip. p. 293.

Tremors of the ſounding Body; and the quicker the Succeſſion of the Vibrations is, the acuter is the Tone, and *è contra.*

A muſical Chord performs all its Vibrations, whether great or ſmall, in the ſame Time. For, if a String is ſtretched between two Pins, and a Force is applied to the middle Point, to draw it out of its rectilineal Situation; it is found by Experiment, that the Diſtance (if it be ſmall) to which it is drawn, is as the Force applied; conſequently the Velocity, with which it returns, when left to itſelf, will be as the Space it has to move over; it will therefore perform all its Vibrations in the ſame Time: This is the Reaſon why the ſame Chord, however ſtruck, produces the ſame Note. It is alſo found by Experiment, that when Strings of equal Diameters, but different Lengths, are equally ſtretched, the longer they are, ſo much the leſs Weights will draw them from their rectilineal Situation to the ſame Diſtance;

Upon this Principle it is, that Sound is conveyed from one Side of a *Whiſpering* Gallery to the oppoſite one, without being perceived by thoſe who ſtand in the Middle. The Form of a *Whiſpering* Gallery is that of a Segment of a Sphere, or the like arched Figure; and the Progreſs of the Sound through it may be illuſtrated in the following Manner.

Let ABC (*Fig.* 14.) repreſent the Segment of a Sphere; and ſuppoſe a low Voice uttered at D, the Vibrations expanding themſelves every Way, ſome will impinge upon the Points E, E, *&c.* and from thence be reflected to the Points F, from thence to G, and ſo on, till they all meet in C; and by their Union there cauſe a much ſtronger Sound, than in any other Part of the Segment whatever, even at D the Point from whence they came.

the Forces therefore by which they return are leſs, and the Times of their Vibrations longer.

When two Chords perform their Vibrations in equal Times, the Tone produced is called an *Uniſon*. If one performs two, while the other one; 'tis an *Octave*. If one three, while the other two; 'tis a *Fifth*. If one three, while the other four; 'tis called a *Fourth*, &c.

To make an Uniſon Sound, it is not neceſſary, that the Vibrations of the two Strings ſhould actually concur, but only that they ſhould be performed in equal Times; ſo that they would always concur, if they began at the ſame Inſtant. For the Ear perceives not the ſingle Vibrations diſtinctly, but only finds that Difference, which proceeds from the Intervals of Time, that paſs between them *.

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* Upon theſe Principles we may account for that remarkable Phænomenon in *Muſic*, that an intenſe Sound being raiſed, either with the Voice, or a ſonorous Body, another ſonorous Body near it, and in Uniſon with it, will thereby be made to ſound. For the Vibrations of the Air, which correſpond to the Tremors of the firſt ſounding Body, agreeing exactly, in Point of Time, with thoſe, which are capable of being given to the other Body at Uniſon with it; when they have by their firſt Impulſe communicated a ſmall Degree of Motion to it, will, by conſpiring with it, as it moves forwards and backwards, continually increaſe its Motion, till it becomes ſenſible. The contrary happens in Strings which are in Diſcord with each other; for in this Caſe, though the firſt Vibration of one may give Motion to the other, yet their Vibrations not being performed in equal Times, the ſecond will come *unſeaſonably*, *i. e.* when the other is moving the contrary Way, and obſtruct its Motion. It is farther obſervable, that in two Strings, one of which vi-

brates twice, while the other once; if the firſt be ſounded, the two Extreams of the other will each ſound an Uniſon with it, while the middle Point remains at Reſt. So if one vibrates thrice, while the other once, the laſt will be divided into three Parts, each of which will ſound an Uniſon with it, and the two Points between thoſe Parts will remain at Reſt. For otherwiſe, that which vibrates twice, while the other once, muſt neceſſarily interfere with it at every ſecond Vibration; and that which vibrates thrice, while the other once, would interfere with it at every third; ſo that it would not be put into a ſufficient Motion to produce a Sound. But, when it is divided by the quieſcent Points, it becomes ſo many Strings at Uniſon with the former, each of which eaſily receives its Vibrations from thence.

From hence likewiſe it is, that if we take two or three drinking Glaſſes, and put ſome Water or other Fluid into each of them, and place them near to each other, taking Care to fill them to ſuch Heights, that (when ſtruck) their Tones ſhall be in Uniſon; and then, if we ſlide the Finger along the Brim of one of the Glaſſes, preſſing pretty ſtrongly upon it, (which will cauſe it to ſound) we ſhall ſee the Surface of the Fluids in the other Glaſſes begin to tremble; which ſhews that the Vibrations of the firſt Glaſs cauſe the like in the other at Uniſon with it; though not perhaps in a Degree ſufficient to produce a Sound, ſtrong enough to be heard diſtinctly from the former.

Thus it is that ſome Perſons are able to break a drinking Glaſs by a Tone of their Voice at Uniſon with it. They firſt try the Tone of the Glaſs by ſtriking it, then applying their Mouth near to the Brim of it, ſound the ſame Note with their Voice; this ſets the Glaſs a trembling; they then continually raiſe their Voice, ſounding ſtill the ſame Note; this encreaſes the Tremors of the Glaſs, which by that Means (if it is not too ſtrong) is broke in Pieces.

The Effect of *Muſic* upon Perſons bit with the *Tarantula*, (if the Accounts we have of it from Abroad may be credited) is very ſurpriſing. A Perſon bit with the *Tarantula* after ſome Time loſes both Senſe and Motion, and dies if deſtitute of Help. The moſt effectual Remedy is *Muſic*. The Muſician tries Variety of Airs, till he hits upon one that affects the Patient, who upon that begins to move by Degrees; firſt keeps Time with his Fingers, Arms, and Legs, afterwards is violently agitated in every Part of his Body; and then leaps up, begins to dance, and encreaſes in Activity every Moment; till after five or ſix Hours, being very much fatigued, he is put to Bed, and left to ſweat. The next Day the ſame Air brings him out of Bed for a new Dance. Which Exerciſe being thus continued, the Diſtemper is abated in the Space of four or five Days, the Effects of the Bite being in ſome Meaſure carried off by Sweat, and the Patient begins then to recover his Senſe and Knowledge by little and little.

The Reaſon why the Patient is thus affected by the *Muſic*, is becauſe the Nerves of his Body are ſo diſpoſed in that Diſtemper, as eaſily to be agitated by the Vibrations which are occaſioned by the Principle and ſtronger Notes of what is played.

See on the Subject of this Diſſertation, Philoſoph. Tranſact. No. 134, 234, 302, 313, 319, 337. Hiſt. de l'Acad. 1702, 1708. *Grew*'s Coſmolog. Sacr. Book I. Chap. 5. *Mead* upon Poiſons, p. 59. *Keil*'s Anatomy, p. 214. *Baglivi* Prax. Medic. Diſſert. I. *Bellini* de Urinis & Pulſibus, &c. ſub fine Capitis de Mania.

DIS-

DISSERTATION II.

Of Capillary Tubes.

BY a *Capillary Tube* is generally underſtood a Glaſs Pipe; the Diameter of whoſe Bore is at moſt but about one tenth of an Inch; though any Tube whoſe Cavity does not exceed that Magnitude, may be ſo called.

The Phænomena of Capillary Tubes being ſuch as contradict a known Law in *Hydroſtatics*, viz. *that a Fluid riſes in a Tube to the ſame Height with the Level of its Source* *; and likewiſe of Affinity with the Aſcent of the Sap through the Stems of Plants for the Nouriſhment of their Fruit, and with divers other Operations of Nature: it has been thought of no ſmall Moment in Philoſophy to find out and eſtabliſh their true Cauſe; which after numerous Experiments, and ſeveral Conjectures about it, is found to be no other than the Attraction of Coheſion; by which ſmall Particles of Matter mutually adhere together, and form larger Bodies †. I ſhall law down the ſeveral Phænomena, as ſo many Matters of Fact; and ſubjoin to each a Solution from that Cauſe. In Order to which, it may not be improper to premiſe the following Conſideration by Way of *Lemma.*

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* See Chap. I. §. 9. Caſe 4. in the Notes.

† See *Haukſbee*'s and *Power*'s Experiments. *Muſſchenbroeck* 4to Edit. Philoſoph. Tranſact. No. 355. Mem. de l'Acad. 1705, 1714, 1722, 1724. With others referr'd to in Quæſtiones Philoſoph.

Let us ſuppoſe the Veſſel ABCD (*Fig.* 15.) filled with a Fluid to the Height LM, and let it be conceived as divided into the equal Portions EFGH, GHIK, IKLM, *&c.* Farther, let it be ſuppoſed, that each Particle of Matter in the inner Surface of the Veſſel, has a Sphere of Attraction, whoſe Semidiameter is equal to the Breadth of three of thoſe Portions; that is to ſay, that the Attraction of the Particle M reaches upwards as far as F, and downwards as far as S; and that of the Particle O, upwards as far as H, and downwards as far as U; and ſo of all the reſt quite round the Tube. From hence it will follow, that every Particle of the inner Surface of the Veſſel, which lies between EF and RS, conſpires in endeavouring to raiſe the Fluid towards AB the Top of the Veſſel; and that the Fluid is not affected by any other. For Inſtance, the Particle S, and all below it, will attract downwards three Strata of the Fluid (ſuch as are contained in three equal Diviſions of the Veſſel) from above, and as many upwards from below; and therefore will have no Effect at all in raiſing or depreſſing the Fluid. But the Particle Q will attract only two Strata downwards; becauſe there are no more above it, and three upwards, and therefore will in ſome Meaſure tend to raiſe the Fluid; ſo the Particle O will attract but one downwards, and three upwards; the Particle M none downwards, and three upwards; the Particle K two upwards, and H only one: all which may clearly be ſeen by their Situations in the Figure with Reſpect to the Surface of the Fluid. Therefore in every Veſſel, where there is a mutual Attraction between the Fluid it contains and the Particles of which it is compoſed, there will be a certain Number of Particles diſpoſed around it in Form of a broad Periphery or Zone, as repreſented by AB; (*Fig.* 16.) half of which lies above the Surface of the Fluid, and half below it, and will tend to make it riſe towards the Top. This being underſtood, the following Phænomena will not be difficult *.

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* I have been the more particular in explaining this *Lemma*, becauſe it is not a bare *Periphery* of no Breadth, to which the Aſcent of the Fluid is owing, but a *Zone* or *Cingulum* of Particles diſtended equally in Breadth both ways from the Surface of the Fluid; and becauſe it is upon the Breadth of this, that ſome of the following Solutions depend. As to the Thickneſs of it, that undoubtedly is equal to the Semidiameter of the Sphere of Attraction in the Particles of the Veſſel; and therefore Veſſels, whoſe Sides are of different Thickneſſes (provided thoſe Thickneſſes be leſs than that Semidiameter) muſt have different Effects upon the ſame Fluid, though no one has as yet been ſo accurate as to obſerve it. The Reaſon why a Fluid will not riſe in a large Veſſel, as well as in one that is Capillary, is becauſe the Attraction of its Particles does not reach far enough into the Middle of the Veſſel; and therefore it only riſes about the Sides, ſtanding higher than in the Middle: as may be ſeen in a Drinking-Glaſs, when a Quantity of Water is put into it, ſomewhat leſs than is ſufficient to fill it.

I. Let there be two Capillary Tubes, AB and CD (*Fig*. 17.) open at both Ends; and having their lower Orifices, A and C, immerged below the Surface of the Water contained in the Veſſel FGHI: The Water will immediately riſe up in each Tube above the Surface of that in the Veſſel, beginning with a ſwift Motion, which will gradually decreaſe; till as much Water has entered the Tubes, as they are able to raiſe: And the Heights to which the Water will riſe in them, will be reciprocally as their Diameters.

That the Water ought to riſe in both Tubes is an immediate Conſequence of the foregoing *Lemma*; becauſe the Column of Water within the Tube is rendered lighter than an equal Column on the Outſide, as being attracted upwards by a Portion of the interior Surface of the Veſſel; and therefore will riſe till it becomes as much longer than the external ones, as it is made lighter; that the *Æquilibrium*, which was deſtroyed by the Attraction of the Tube, may be reſtored by the Weight of the Column. The Reaſon that the Velocity with which it riſes, ought conſtantly to decreaſe, is, becauſe the heavier the Column is, the leſs is the Effect of the Attraction, which is always the ſame in a Tube of the ſame Diameter. And laſtly, the Heights to which the Water riſes in them, will be reciprocally as their Diameters; for then the Quantities raiſed will be directly as the Diameters *; but the Peripheries that raiſe them, (being always of the ſame Breadth, and having their Lengths equal to the Circumferences of the Tubes) are as thoſe Diameters; the Quantities of Water therefore, being in the ſame Ratio, are as the Peripheries, *i. e.* as the Cauſes by which they are raiſed.

II. If the Tubes, before they are immerged in the Water, are filled to greater Heights, than thoſe to which it would naturally riſe in them; and then have their lower Orifices immerged in Water, the Water will ſubſide till it ſtands in each at the ſame Height to which it would have riſen; but, if they are held in a perpendicular Poſition without being immerged, the Water will not ſubſide in the Tubes *quite* ſo far.

The Reaſon why the Water in the Tube, when its lower Orifice is immerged, ſubſides to the ſame Height it would have riſen to, had the Tube been immerged when empty, is becauſe the Column is ſuſpended in one Caſe by the ſame Cauſe, by which it is raiſed in the other; but when the Tube full of Water is held erect, without being immerged, it will not ſubſide *quite* ſo far; becauſe the lower End of the Tube, which the Water leaves behind it as it drops out, attracts it the contrary Way; ſo that the Column in this Caſe is ſuſpended, not only by the inner Surface of the Tube at the Top, but alſo by its lower End; and therefore a greater Quantity of Water is ſuſpended than in the former Caſe.

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* The Heights to which the Water riſes, being in a reciprocal Ratio of the Diameters; and the Contents of Cylindrical Tubes being in a direct Ratio of their Heights, and of the Squares of their Diameters; the Quantities of Water raiſed in this Caſe will be in a reciprocal Ratio of the Diameters, and a direct one of the Squares of the ſame. Now theſe two Ratio's being compounded together, give the direct one of the Diameters themſelves; becauſe the ſimple reciprocal Ratio deſtroys one of thoſe, which are contained in the direct one of the Squares.

III. If a Tube, having its lower Orifice immerged in Water, be held obliquely, it will raiſe the Water to the ſame perpendicular Height, as when held erect.

For ſince Fluids preſs according to their perpendicular Heights, the Weight of the Column raiſed will not be proportionable to the attractive Force of the Tube, till it has arrived at the ſame perpendicular Height, to which it would have roſe, if held erect.

IV. If a Tube, when the Water is riſen into it to its wonted Height, is laid in an Horizontal Situation, the Water will move towards the Middle of the Tube, leaving the End which was immerſed a little behind.

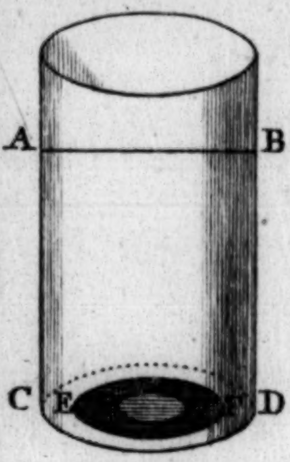
The Solution of this Phænomenon depends on what was obſerved in the *Lemma* about the Breadth of the attracting Periphery, and its being equally ſituated on each Side the Surface of the Water; for from thence it follows, that if the Water ſhould not run from the full End of the Tube, after it has laid in an Horizontal Situation, but remain contiguous to it; that End of the Column of Water would be attracted only by ſuch a Portion of a Periphery as lies within its Surface at that End; becauſe the End of the Tube coinciding with the Surface, the other Half of the Periphery is wanting. Whereas, at the other End of the Column, there is a Periphery whoſe Breadth is entire; which overpowering the other, cauſes the Water to move towards the Middle of the Tube, till as much Periphery is left behind, as can at once affect the Water by the Attraction of its Particles; after which the Water being attracted equally each way, remains at Reſt.

V. Let there be a Tube (*Fig.* 18.) conſiſting of two Parts, DR and RCK, of different Diameters; it follows from what has been ſaid, that DR the ſmaller Part of the Tube, is able to raiſe Water higher than the other: Let then the Height to which the larger would raiſe it, be TF, and that to which it would riſe in the leſſer (was it continued down to the Surface of the Fluid) be XL. If this compound Tube be filled with Water, and the larger Orifice CK be immerſed in the ſame Fluid, the Surface of the Water will ſink no farther than XL; the Height to which the leſſer Part of the Tube would have raiſed it.

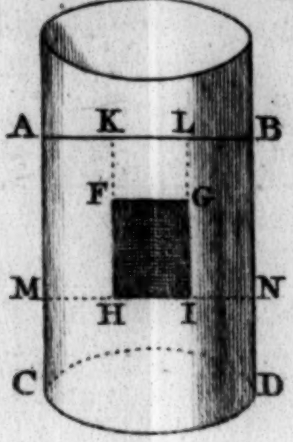
But if the Tube be inverted, as in *Fig.* 19. and the ſmaller Orifice XL be immerſed, the Water will run out till the Surface falls to TF; the Height to which the larger Part of the Tube

Part II. Plate III. p.62.

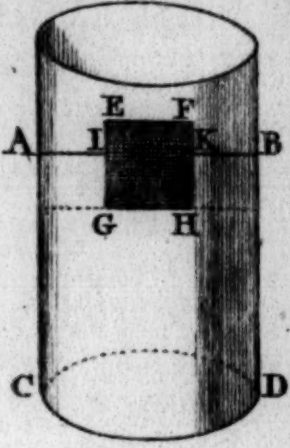
F.11. p.25.



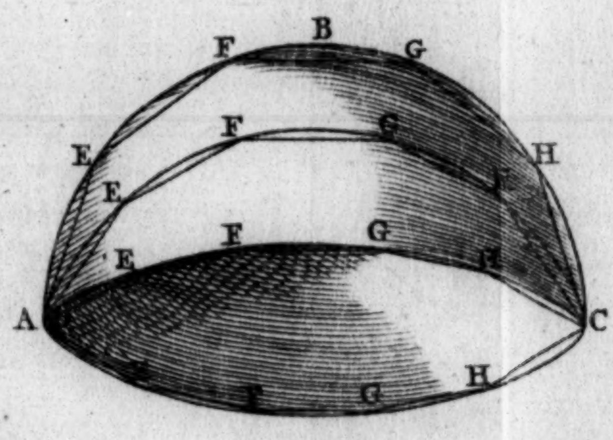
F.12. p.28.



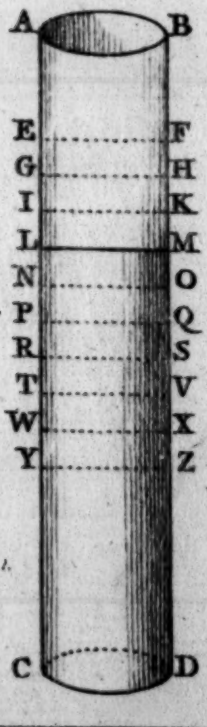
F.13. p.29.

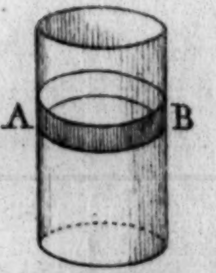


F.14. p.53.



F.15. p.58.





F.16. p.59.

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Tube would have raiſed it. The Size of the lower Part making no Alteration in the Height, at which the Fluid is ſuſpended in either Caſe.

In order to account for theſe Phænomena, it muſt be conſidered, that when a Body is ſo diſpoſed, that its different Parts ſhall move with different Degrees of Velocity, the greater Proportion the Velocity of that Part to which a moving Power is applied, bears to that of the reſt; ſo much the more *effectual* is the Power in moving that Body: As is the known Caſe of the *Lever*, and all the other *Mechanical* Powers.

Now let us conceive the Tube, DR (*Fig.* 18.) continued down to HI, and let it be ſuppoſed at preſent that the Fluids contained in the Tube XLHI, and the compound one XLKC, are not ſuſpended by the Periphery at L, but that they preſs upon their reſpective Baſes, HI and CK. Let it farther be ſuppoſed that theſe Baſes are each of them moveable, and that they are raiſed up or let down with equal Velocities; then will the Velocity with which XL the uppermoſt Stratum of the Fluid XLCK moves, exceed that of the ſame Stratum, conſidered as the uppermoſt of the Fluid in the Tube XLHI, as much as the Tube RCK is wider than DR (by the *Lemma*, Chap. 1. §. 9.) that is, as much as the Space MNKC exceeds XLIH; conſequently by what was obſerved in the foregoing Paragraph, the

Effect of the attracting Periphery XL, as it acts upon the Fluid contained in the Veſſel XLCK, exceeds its Effect, as it acts upon that in XLHI, in the ſame Proportion. Since therefore it is able (*ex Hypoth.*) to ſuſtain the Weight of the Fluid XLHI by its natural Power, it is able under this *Mechanical* Advantage, to ſuſtain the Weight of as much as would fill the Space MNKC: But the Preſſure of the Fluid XLCK is equal to that Weight, as having the ſame Baſe and an equal Height (Chap. 1. §. 9.) its Preſſure therefore, or the Tendency it has to deſcend in the Tube, is equivalent to the Power of the attracting Periphery XL, for which Reaſon it ought to be ſuſpended by it.

Again, the Height (*Fig.* 19.) at which the attracting Periphery in the larger Part of the Tube is able to ſuſtain the Fluid is no greater than NF, that to which it would have raiſed it, had the Tube been continued down to MN. For here the Power of the attracting Periphery acts under a like *Mechanical* Diſadvantage; and is thereby diminiſhed in Proportion to the Capacity of the Tube TFNM to that of HIXL; becauſe, if the Baſes of theſe Tubes are ſuppoſed to be moved with equal Velocities, the Riſe or Fall of the Surface of the Fluid TFXL, would be ſo much leſs than that of TFMN. And, whereas the attracting Periphery TF is able by its natural Power to ſuſpend the Fluid only to the

Height NF in the Tube TFMN; it is in this Caſe able to ſuſtain no greater Preſſure than what is equal to the Weight of the Fluid in the Space HIXL: but the Preſſure of the Fluid TFXL, which has equal Height, and the ſame Baſe with it, is equal to that Weight; and therefore is a juſt *Æquipondium* to the attracting Power.

VI. From hence we may clearly ſee the Reaſon, why a ſmall Quantity of Water put into a Capillary Tube, which is of a Conical Form, and laid in an Horizontal Situation, will run towards the narrower End. For let AB (*Fig.* 20.) be the Tube, CD a Column of Water contained within it; when the Fluid moves, the Velocity of the End D will be to that of the End C reciprocally as the Cavity of the Tube at D, to that at C (by the *Lemma*, Chap. 1. §. 9.) that is, reciprocally as the Square of the Diameter at D, to the Square of the Diameter at C *; but the attracting Periphery at D is to that at C, in the ſimple Ratio of the Diameter at D, to the Diameter at C. Now, ſince the Effect of the Attraction depends, as much upon the Velocity of that Part of the Fluid where it acts, as upon its natural Force, its Effect at D will be greater than at C; for though the Attraction at D be really leſs in itſelf than at C, yet its Loſs of Force upon that Account, is more than compenſated by the *mechanical* Advantage it has ariſing from hence, *viz.* that the Velocity of the Fluid in that Part is greater than it is at C, in a greater Proportion than the Force itſelf is leſs: The Fluid will therefore move towards B.

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* 12 *El.* 2.

VII. From hence likewiſe it follows, that if a Veſſel, as ABC (repreſented *Fig.* 21.) of any Form whatever, have its upper Part drawn out into a Capillary Tube as B; and if this Veſſel is filled with Water, and have its lower Orifice placed on FD the Surface of the ſame Fluid; then the Water will remain ſuſpended in the Veſſel, provided the Capillary at the Top be ſmall enough (was it continued down to the Bottom) to raiſe the Fluid to the Height B. Becauſe, by Propoſition the fifth, the lower Part of the Tube makes no Alteration in the Height, at which the Capillary B is able to ſuſtain the Fluid.

VIII. And if the ſame Veſſel be filled only to the Height DE (*Fig.* 22.) and a Drop of Water be put into the Capillary at B, the intermediate Part BDE being full of Air) the Water will continue ſuſpended at the Height DE.

For, although the Fluid ACDE is not in Contact with the Drop of Water in the Capillary Tube, and therefore not immediately ſupported by it; yet the Preſſure of the Atmoſphere upon the Surface FG, and againſt the upper Part of the Drop in the Capillary B, keeps the Fluid ADEC, and the Drop, and the intermediate Air from ſeparating, juſt as in the former Caſe the Attraction of Coheſion in the Particles of the Water prevented a Separation between that in the Veſſel and that in the Capillary. Conſequently, as the Water in the Capillary was able in the former Caſe to ſuſtain as much Fluid as the Veſſel could contain, it is now ſufficient to ſuſtain the Fluid ADEC *.

IX. Let there be a Capillary Siphon, as that repreſented, *Fig.* 23, 24 or 25, and let EF be the Height, to which Water might be raiſed by a Periphery equal to that at A. Now, ſince (as was obſerved, §. 2.) the lower End of a Tube when it is not immerged, cauſes a longer Column to be ſuſpended than otherwiſe would be; that is, it ſupports a ſhort Column beſides that which is ſuſtained by the attracting Periphery; let HI be the Height of ſuch a Column as might be ſuſpended by the End C: then, if any of thoſe Tubes are filled with Water, and held as in the Figure (neither End being immerged) the Fluid will run out of the Tube at C, if CD the Difference of the

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* This happens quite otherwiſe in Vacuo, becauſe the Preſſure of the Air, which, as it were, connects the Drop with the Water ADEC, being wanting, it immediately falls for Want of a Support. Whereas the former Phænomenon equally ſucceeds in Vacuo; which ſhews that the Parts of the Fluid in the Veſſel are connected with each other, and with that in the Capillary by their own mutual Attraction of Coheſion, there being nothing elſe whereby they can be ſupported.

Legs exceeds EF and HI added together, otherwiſe not.

For the Column AB is a Counterpoiſe to BD, being of the ſame perpendicular Height; and therefore it is only the Weight of the Column CD, which determines the Fluid to move; unleſs that Weight therefore exceeds the Force of the attracting Periphery at A (which the Fluid AB muſt leave in riſing up the Tube) and alſo what may be ſupported by the End C, that is, (*ex Hypoth.*) two Columns whoſe Heights are EF and HI, it cannot run out at C; otherwiſe it will, as being deſtitute of a ſufficient Support.

X. If the End A is immerged in Water, and the other not (ſuppoſing the Tube full as before,) it will run out at C, though CD the Difference of the Legs, only exceeds HI. For then the Attraction at A ceaſes, and there is nothing to ſupport the Column CD, but the Power the End C has to prevent Drops from falling off it.

XI. Again, if the End C is immerged in Water, (and the other not) it will run out at C, if CD exceeds EF, otherwiſe not.

For in this Caſe, there is nothing to ſupport the Column CD, but the attracting Periphery at A, whoſe Power is ſuppoſed able to raiſe a Column as EF, and no more.

XII. And, if both Ends are immerſed (the Tube being ſuppoſed full as before) the Water will run out at the lower, which ever it is.

For then the Attraction of both Ends ceaſes; and the longer Column over-balancing the ſhorter, the Fluid is determined thereby to run out at the lower End.

XIII. If either of the Tubes (*Fig.* 23 or 24.) are ſmall enough to raiſe the Water from A to B, and if the Orifice A is immerged, the Fluid will riſe to B, paſſing on to C, where it will run out or be ſuſpended according to the foregoing Caſes: but if the Periphery at G (*Fig.* 25.) is ſuch as would ſupport a Column of the Length of AM only, and if the Tube be filled from A to G (the Extremity A being ſtill immerged as before) the Liquor will proceed no farther, but remain in the Poſition in which it is put.

For that Fluid which has paſſed B aſſiſts by its Weight the attracting Periphery in raiſing the Column AB, and therefore it runs down to C. But, if when the Tube is filled to G, the Periphery there is not able to ſupport more than AM the Difference of the Legs AB and BG, the Fluid muſt neceſſarily ſtand there; ſince BG is no more than a Counterpoiſe to MB, and AM is ſuppoſed to be as much as the Periphery at G can ſuſtain.

XIV. Tho' a Capillary Tube be ſhorter than the Height to which its attracting Periphery is able to raiſe a Fluid, *v. g.* tho' the Tube AB (*Fig.* 26.) be ſmall enough (was it of ſufficient Length) to raiſe Water as high as C; yet when the End A is immerged, the Fluid will not run out at B, but only be ſuſpended at that Height.

For when the Fluid is riſen as high as B, it has then no more Periphery above it, to attract it any farther; and if it was forced up a little above the End, it would be attracted back again by it *.

XV. The Aſcent of different Fluids in the ſame Tube is various. *Muſſchenbroek* has found, that in a Tube in which Water will riſe to the Height of twenty-ſix Lines, Oil of Wormwood will riſe but eighteen or nineteen, whereas Urine will riſe thirty-three or thirty-four.

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* Hence we ſee the Abſurdity of ſuppoſing that a Fluid may be made continually to flow from a lower Place to an higher by a Capillary Tube, as ſuch; for whether the Tube be of ſuch Form, as is repreſented, *Fig.* 23, 24, 25, or 26, the Fluid will always ſtop when it comes at the higher End; becauſe the Attraction is then in a Direction contrary to its Motion; and the Weight of the whole Fluid, if the Tube is ſtraight, or of ſo much as is contained in DC, the Difference of the Legs, if it be crooked, is likewiſe an Impediment in it.

Hence alſo the Abſurdity of ſuppoſing a Fluid to *circulate* by Virtue of a Capillary Tube, as ſuch. For ſuppoſe the Ends of the Capillary Tube joined together, ſo that the Tube ſhall return into itſelf; if the Tube be not full of Liquor, the Liquor will place itſelf as near as poſſible to the ſmalleſt Part of the Tube, as may eaſily be inferred from what was obſerved in §. 6. and will reſt there: if it be full, in which Caſe the Extremities of the Fluid join, then there is no Periphery or Zone of Particles lying part out of the Fluid, and part in it, and conſequently all Ground or Cauſe of Motion, ſo far as it ariſes from the Tube being *capillary*, is entirely taken away. And if Part of the Tube be capillary, and Part not, the Caſe is ſtill the ſame. How ridiculous then is it to affirm, as ſome have done, that the Circulation of the Animal Fluids is promoted by the Paſſages through which they flow, being of that Kind.

The Reaſon of which is, becauſe ſome Fluids are attracted more ſtrongly by Glaſs, than others are. Mercury exhibits Phænomena juſt the Reverſe of the former; for if the End of a Capillary Tube be immerſed below the Surface of that Fluid, it will not riſe in the Tube to a Level with that on the Outſide. This is becauſe the Particles of Mercury attract each other more forcibly than they are attracted by thoſe of Glaſs *.

* See *Jurin*'s Diſſert. Philoſoph. Tranſ. No. 363.

According to *Muſſchenbroek* the Length of the upper Part of a Tube, which is above the Height to which it is able to raiſe a Fluid, conduces ſomething towards the raiſing it; and therefore in a longer Tube a Fluid riſes higher than in one of the ſame Dimenſions that is ſhorter; and if a Tube, with ſo much Fluid contained in it, as it is able to raiſe, be laid in an Horizontal Situation, the Fluid will run to the Middle of it. But of this I have had no Experience: 'Tis poſſible that ingenious Profeſſor, tho' very accurate in making Experiments, might herein be deceived. He acknowledges, (Experiment the fifteenth) that it ſometimes happens otherwiſe.

Other Authors, beſides thoſe already referred to, that have treated on this Subject, are *Boyle* Exper. Phyſ. Mech. Exp. 9. *Sturmius* Colleg. Cur. Tentam. 8. *Bernoulli* Gravit. Æth. *Hooke* Microg. Obſer. 6. *Leeuwenhoek* Continuat. Arcan. Nat. Epiſt. 131. *Sinclaire* Art. Gravit.

DISSERTATION III.

Of the Origin of Fountains.

MANY have been the Conjectures of Philoſophers concerning the Origin of Fountains; and great Pains have been taken both by the Members of the Royal Society, and thoſe of the Academy of Sciences at *Paris*, in order to aſcertain the true Cauſe of it. It was ARISTOTLE's Opinion, and held by moſt of the antient Philoſophers after him, that the Air contained in the Caverns of the Earth, being condenſed by Cold near its Surface, was thereby changed into Water; and that it made its Way through, where it could find a Paſſage. But we have no Experience of any ſuch Tranſmutation of Air into Water.

Thoſe who imagine that Fountains owe their Origin to Waters brought from the Sea by ſubterraneous Ducts, give a tolerable Account how they loſe their Saltneſs by Percolation as they paſs through the Earth; but find great Difficulty in explaining by what Power the Water riſes above the Level of the Sea, to near the Tops of Mountains, where Springs generally abound; it being contrary to the Laws of *Hydroſtatics*, that a Fluid ſhould riſe in a Tube above the Level of its Source. However, they have found two Ways, whereby they endeavour to extricate themſelves from this Difficulty. The one is that of DES CARTES, who imagines, that after the Water is become freſh by Percolation, it is raiſed out of the Caverns of the Earth in Vapour towards its Surface; where meeting with Rocks near the Tops of Mountains in the Form of Arches or Vaults, it ſticks to them, and runs down their Sides, (like Water in an Alembic) till it meets with proper Receptacles, from which it ſupplies the Fountains. Now, this is a mere *Hypotheſis* withou Foundation or Probability; for in the firſt Place we know of no internal Heat of the Earth to cauſe ſuch an Evaporation; or if that were allowed, yet 'tis quite incredible, that there ſhould be any Caverns ſo ſmooth, and void of Protuberances, as to anſwer the Ends of an Alembic, in collecting and condenſing the Vapours together, in every Place where Fountains ariſe. There are others (as VARENIUS, *&c.*) who ſuppoſe that the Water may riſe through the Pores of the Earth, as through Capillary Tubes by Attraction; but hereby they ſhew, that they are quite unacquainted with what relates to the Motion of a Fluid through ſuch Tubes. For when a Capillary Tube opens into a Cavity at its upper End, or grows larger and larger, ſo as to ceaſe to be Capillary at that End; the Water will not aſcend through that Tube into the Cavity, or beyond where the Tube is Capillary; becauſe that Part of the Periphery of the Cavity, which is partly above the Surface of the Water, and partly below it, is not of the Capillary Kind. Nay, if the Cavity is continually ſupplied with Water, it will be attracted into the Capillary Tube, and run down it, as through a Funnel, if the lower End is immerged in the ſame Fluid, as in this Caſe it is ſuppoſed to be *.

It has been a generally received Opinion, and much eſpouſed by MARRIOTTE (a diligent Obſerver of Nature) that the Riſe of Springs is owing to the Rains and melted Snow. According to him, the Rain-Water, which falls upon the Hills and Mountains, penetrating the Surface, meets with Clay or Rocks contiguous to each other, along which it runs, without being able to penetrate them, till being got to the Bottom of the Mountain, or to a conſiderable Diſtance from the Top, it breaks out of the Ground, and forms Springs.

In Order to examine this Opinion, Mr. PERRAULT, DE LA HIRE, and D. SIDELEAU endeavour'd to make an Eſtimate of the Quantity of Rain and Snow, that falls in

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* See the foregoing Diſſertation, Sect. 14.

the Space of a Year, to ſee whether it would be ſufficient to afford a Quantity of Water, equal to that which is annually diſcharged into the Sea by the Rivers. The Reſult of whoſe Inquiries was, that the Quantity of Rain and Snow which fell in a Year into a Cylindrical Veſſel, would fill it (if ſecured from evaporating) to the Height of about nineteen Inches. Which Quantity D. SIDELEAU * ſhewed, was not ſufficient to ſupply the Rivers; for that thoſe of *England*, *Ireland*, and *Spain* diſcharge a greater Quantity of Water annually, than the Rain, according to that Experiment, is able to ſupply. Beſides which, another Obſervation was made by them at the ſame Time, *viz.* that the Quantity of Water raiſed in Vapour one Year with another, amounted to about Thirty-two Inches, which is thirteen more than falls in Rain: A plain Indication, that the Water of Fountains is not ſupplied bv Rains and melted Snow.

Thus, the true Cauſe of the Origin of Fountains remained undiſcovered, till Dr. HALLEY in making his Celeſtial Obſervations upon the Tops of the Mountains at St. *Helena*, about eight Hundred Yards above the Level of the Sea, found that the Quantity of Vapour which fell there (even when the Sky was clear) was ſo great that it very much impeded his Obſervations, by covering his Glaſſes with Water every half Quarter of an Hour; and upon that attempted to determine by Experiment the Quantity of Vapour, exhaled from the Surface of the Sea, as far as it riſes from Heat; in order to try, whether that might be a ſufficient Supply for the Water continually diſcharged by Fountains. The Proceſs of his Experiment was as follows. He took a Veſſel of Water ſalted to the ſame Degree with that of Sea-Water, in which he placed a Thermometer; and by means of a Pan of Coals, brought the Water to the ſame Degree of Heat, which is obſerved to be that of the Air in our hotteſt Summer: This done, he affixed the Veſſel of Water with the Thermometer in it, to one End of a Pair of Scales, and exactly counterpoiſed it with Weights on the other. Then, at the End of two Hours, he found by the Alteration made in the Weight of the Veſſel, that about a ſixtieth Part of an Inch of the Depth of the Water, was gone off in Vapour; and therefore in twelve Hours, one tenth of an Inch would have gone off. Now this accurate Obſerver allows the *Mediterranean Sea* to be forty Degrees long, and four broad; (the broader Parts compenſating for the narrower; ſo that its whole Surface is one Hundred and ſixty ſquare Degrees;) which according to the Experiment muſt yield at leaſt five Thouſand, two Hundred and eighty Millions of Tons of Water. In which Account, no Regard is had to the Wind, and the Agitation of the Surface of the Sea; both which undoubtedly promote the Evaporation.

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* Memoirs of the Royal Academy of Sciences for the Year 1693.

It remained now, to compare this Quantity of Water, with that, which is daily conveyed into the ſame Sea, by the Rivers. The only Way to do which, was to compare them with ſome known River; and accordingly he takes his Computation from the River *Thames*, and to avoid all Objection, makes Allowances, probably greater, than what were abſolutely neceſſary.

The *Mediterranean* receives the following conſiderable Rivers, *viz.* the *Iberus*, the *Rhone*, the *Tibur*, the *Po*, the *Danube*, the *Nieſter*, the *Boriſthenes*, the *Tanais*, and the *Nile*. Each of theſe he ſuppoſes to bring down ten Times as much Water as the *Thames*; whereby he allows for ſmaller Rivers, which fall into the ſame Sea. The *Thames* then he finds by Menſuration to diſcharge about 20,300,000 Tons of Water a Day. If therefore the abovesaid nine Rivers yield ten Times as much Water as the *Thames* doth, it will follow, that all of them together yield but 1827 Millions of Tons in a Day; which is but little more than one Third of what is proved to be raiſed in Vapour out of the *Mediterranean* in the ſame Time. We have therefore from hence a Source abundantly ſufficient for the Supply of Fountains.

Now having ſound, that the Vapour exhaled from the Sea, is a ſufficient Supply for the Fountains; he proceeds in the next Place to conſider the Manner in which they are raiſed; and how they are condenſed into Water again; and conveyed to the Sources of Springs.

In order to this he conſiders, that, if an Atom of Water was expanded into a Shell or Bubble, ſo as to be ten Times as big in Diameter as when it was Water, that Atom would become ſpecifically lighter than Air; and therefore would riſe ſo long as the Warmth which firſt ſeparated it from the Surface of the Water ſhould continue to diſtend it to the ſame Degree; and conſequently, that Vapours may be raiſed from the Surface of the Sea in that Manner *, till they arrive at a certain Height in the Atmoſphere, at which they find the Air of equal ſpecific Gravity with themſelves. Here they will float, till being condenſed by Cold, they become ſpecifically heavier than the Air, and fall down in Dew, or being driven by the Winds againſt the Sides of Mountains, (many of which far ſurpaſs the uſual Height to which the Vapours would of themſelves aſcend) are compelled by the Stream of the Air to mount up with it to the Tops of them; where being condenſed into Water they preſently precipitate, and

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* See this confuted in Diſſertation 6.

gleeting down by the Crannies of the Stone, Part of them enters into the Caverns of the Hills; which being once filled, all the Overplus of Water that comes thither, runs over by the loweſt Place, and breaking out by the Sides of the Hills, forms ſingle Springs. Many of theſe running down by the Valleys between the Ridges of the Hills, and coming to unite, form little Rivulets or Brooks: Many of theſe again meeting in one common Valley, and gaining the plain Ground, being grown leſs rapid, become a River; and many of theſe being united in one common Channel, make ſuch Streams as the *Rhine* and the *Danube*; which latter, he obſerves, one would hardly think to be a Collection of Water condenſed out of Vapour, unleſs we conſider how vaſt a Tract of Ground that River drains, and that it is the Sum of all thoſe Springs which break out on the South Side of the *Carpathian* Mountains, and on the North Side of the immenſe Ridge of the *Alps*; which is one continued Chain of Mountains from *Switzerland* to the *Black-Sea*.

Thus one Part of the Vapours, which are blown on to the Land, is returned by the Rivers into the Sea, from whence it came; another Part falls into the Sea before it reaches the Land; and this is the Reaſon, why the Rivers do not return ſo much Water into the *Mediterranean* as is raiſed in Vapour. A third Part falls on the Low-Lands, and is the *Pabulum* of Plants, where yet it does not reſt; but is again exhaled in Vapour by the Action of the Sun, and is either carried by the Winds to the Sea, to fall in Rain or Dew there, or elſe to the Mountains, to become the Sources of Springs.

However, it is not to be ſuppoſed, that all Fountains are owing to one and the ſame Cauſe; but that ſome proceed from Rain and melted Snow, which ſubſiding through the Surface of the Earth, makes its Way into certain Cavities, and thence iſſues out in the Form of Springs; becauſe the Waters of ſeveral are found to increaſe and diminiſh in Proportion to the Rain which falls: That others again, eſpecially ſuch as are ſalt, and ſpring near the Sea-ſhore, owe their Origin to Sea-Water percolated through the Earth; and ſome to both theſe Cauſes: Though without doubt moſt of them, and eſpecially ſuch as ſpring near the Tops of high Mountains, receive their Waters from Vapours, as before explained *.

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* There is a certain Species of Springs which ebb and flow alternately, and ſome that ceaſe to flow for a Time, which from thence are called reciprocating or intermitting ones. Their Reciprocations may be accounted for in the following Manner.

Let ABC repreſent one Side of an Hill in which there is a Cavity DEF, and from this a ſubterraneous Duct IKL. Now as this Cavity fills with Water (ſuppoſe from Vapours percolating through the Surface of the Hill, or in any other Manner whatever) its Surface will riſe in the Duct as it does in the Cavity, till it arrives at M, the Level with the upper Part of the Duct; at which Time it will run over at K, filling KLA the other Part of the Duct. Now, if the perpendicular Height of the Point K above L (or rather above A) be greater than its perpendicular Height above I, the Column KLA will overpoiſe the Column KI, and ſo cauſe the Water to run out at A, till its Surface in the Cavity ſinks as far as I, (provided the Duct is large enough to convey the Water away faſter than it enters the Cavity) at which Time the Fountain at A will ceaſe to play, till the Surface of the Water in the Cavity riſes again to M, and runs over at K as before. The Reaſon why the Water continues running (when the Duct is once full) till its Surface ſinks to I, is becauſe the Air preſſing againſt it as it runs out at A, and alſo upon its Surface in the Cavity, keeps the Duct full, as long as the Water in the Cavity is high enough to feed its Orifice at I.

See more on this Subject in Philoſoph. Tranſact. No. 119, 189, 192, 384, 424. Hiſtoire de l'Acad. 1693, 1703, 1713. *Gulielmini* della Natura de Fiumi. *Dale*'s Hiſtory of *Harwich*. *Marriotte*'s Hydroſtatics. *Nieuwentyt* Contempt. 19. *Varenius* Geograph. Cap. 16. *Regnault*, Vol. 2. Converſat. 6. *Hales*'s Statical Eſſays, Vol. 1. Experiment 19. *Micholettus* in Append ad *J. Bernoullii* de Efferveſc.

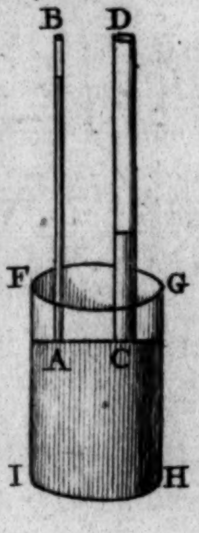
pendicular Height above L the Column KLA will overpower the Column KL, and so cause the Water to run out at L, till the Surface of the Cavity sinks as far as L (provided [illegible] is large enough to convey the Water away [illegible] the Cavity); at which Time the Fountain at A will cease to play, till the Surface of the Water in the Cavity rises again to M, and runs over at K as before. The Reason why the Water continues running when the Duct is once full, till its Surface sinks to L, is because the Air pressing against it at [illegible] and also upon its Surface in the Cavity, [illegible] as long as the Water in the Cavity is high enough to [illegible] to Orifice at L.

See more on this Subject in Philosoph. Transact. No [illegible] 180, [illegible] 224. Histoire de l'Acad. [illegible] [illegible] de Natura de Fonti[illegible] [illegible] Mariotte's Hydrostatics. [illegible] Gassendi. Cap. 15. [illegible] Vol. 1. [illegible] [illegible] Vol. 1. [illegible] [illegible] al J. [illegible] de l'[illegible].

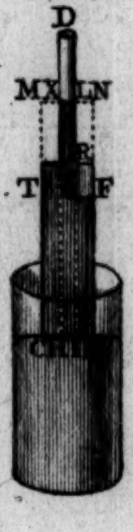
DIS-

Part II. Plate IV. p. 82.

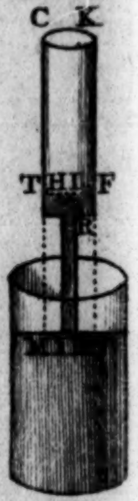
F. 17.
p. 60.



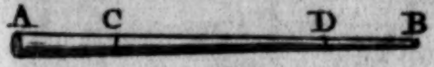
F. 18.
p. 63.



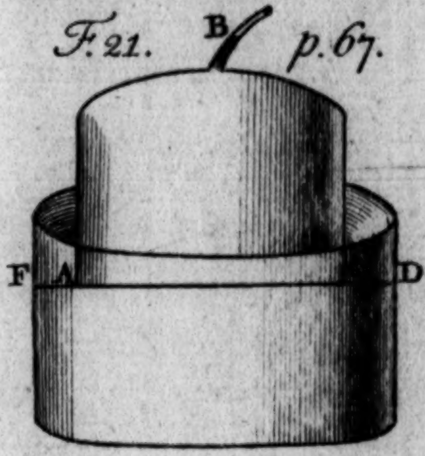
F. 19.
p. 64.



F. 20. p. 66.



F. 21. p. 67.



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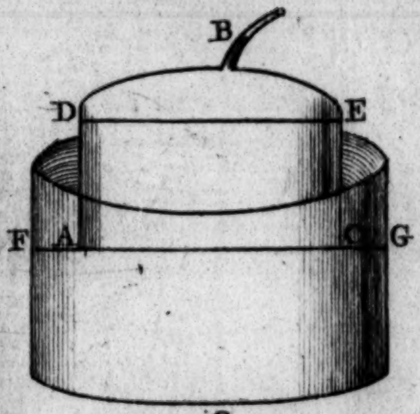
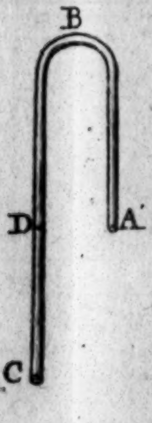


F. 23.



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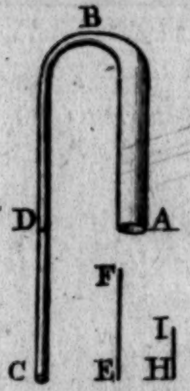
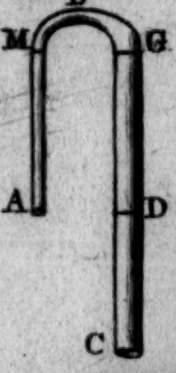
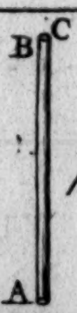


F. 25.



F. 26. p. 81.



F. 27.
p. 71.